Services for an Emission Reduction Project Baseline, Feasibility and Environmental Study

Final Report

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EU SWITCH-Asia funded project:
"Waste to Energy (WtE) for the Rice Milling Sector in Cambodia", EuropeAid/130830/C/ACT/CAI

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This report was prepared by Nexus-Carbon for Development Project Development Unit in cooperation with Dr Simon Shackley – Rice-husk and EIA expert, University of Edinburgh and support from Domrei Research and Consulting.

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Executive Summary

This **Final Report** presents the work carried out by Nexus-Carbon for Development within the ''Emission Reduction Project Baseline, Feasibility and Environmental Study for EU SWITCH-Asia Waste to Energy (WtE) for the Rice Milling Sector in Cambodia'' framework.

The report highlights the **next steps towards the identification of a clear carbon finance route** for the Milling Sector in Cambodia as well as to a sustainable and environmental-friendly integration of rice-husk gasification technology in Cambodia.

The activities completed as part of this study were:

1. Inception report including assignment schedule and work plan
2. Presentation and edition of methodologies and tools for conducting Baseline Study, Feasibility Assessment and Environmental Impact Assessment
3. Compilation study material and secondary data survey
4. Conduct Carbon Baseline, Feasibility Assessment and Environmental Impact Assessment – data collection, field survey, interviews
5. Data entry and analysis, including roadmap design and gap analysis
6. First draft reporting
7. Final report delivery

Results from the **Barrier Analysis** to renewable energy production and consumption show that there are **no major legislative barriers in Cambodia**. Legislative barriers may occur as a result of the environmental impact of disposal of by-products from the gasification process. A Law on Environmental Impact Assessment, setting out provisions, standards and procedures to carry out EIA in Cambodia, is currently being developed. Technical standards on water pollution control - Sub-Decree on Water Pollution Control and quality of drinking water - Drinking Water Quality Standards in particular need to be taken into account during the development of a carbon project in the rice-husk sector. Results from the Barrier Analysis highlight that technical and socio-economic barriers can be identified. Technical barriers are due to the limited skills and knowledge to comply with standards and technical specification of technologies in use. Technical assistance from international experts is indeed needed. Economic barriers stems from the fact that very often energy efficient technologies are more expensive than the traditional ones and require an higher upfront investment. Social barriers stems from the introduction of a new type of technology imported from other countries and dissimilar to technologies specific to Cambodian rice milling sector.

Nexus in cooperation with Domrei carried out a **Baseline Survey**. 30 mills without gasification technology were randomly selected across nine provinces in Cambodia (Banteay MeanChey, Siem Reap, Battambang, Pursat, Kampong Cham, Prey Veng, Kandal, Kampong Speu and Kampong Thom). A convenience sample of 5 mills with gasification systems was also drawn. Data collected during Baseline Survey was used to quantify the baseline emissions (volume of greenhouse gases that would have been emitted if the project were not implemented) to be compared with project emissions. The baseline surveys baseline working practices in the mills. It highlighted the **need for improvements** in record keeping and data management, gender disparities in salaries as well as health and safety practices.

Provided that the gasifiers are using rice husks, the major environmental issues for the gasifiers are the solid and liquid waste streams. The **Environmental Impact Assessment** (EIA) identified environmental externalities by focusing on waste water, sludge and the rice husk char. The data that has been assembled indicates that the black waste water streams generally cause serious localized pollution of end disposal ponds and of streams into which the black water flows. This includes low-level contamination by several heavy metals but, much more seriously, benzene-type molecules and polycyclic aromatic hydrocarbons (PAHs), some of which are known toxicants and which occur in most water and sludge samples tested at high concentrations. Some of this pollution is persistent, as in accumulation of heavy metals in sediments and, potentially, some PAHs.

The rice husk char (RHC) is generally a clean material and can be used for application to soil, though a quantitative risk assessment is advised as one RHC sample did contain moderately high levels of PAHs. At some gasifier sites, sludges are added to RHC piles and this leads to the introduction of contaminants into an otherwise clean soil amendment. Sludges from waste water settling ponds should be treated as a special waste and not introduced into the local environment. Whether any of the pollution discovered can disperse through the water table is not known and was not investigated in this study. A more detailed hydrological analysis and survey would be required to determine whether this is a problem or not but there seems at least a possibility that dispersion could happen for more mobile pollutants.

Any carbon finance project would need to ensure the existence of adequate environmental management plans. The report identified the following **mitigations measures**:

- Adequate **Waste Water** Management systems should be implemented. The waste water treatment system has to be large enough to cope with 100% of the waste water arisings. This might require the use of several waste water treatment systems 'in parallel', where additional units can be brought online as load factor increases.
- **Sludge** from bottom of settling tanks, disposal ponds and discharge streams should be managed as a special waste and disposed of appropriately.
- Procedures for handling **tars** arising from syngas filters should be developed and the tars disposed.
- Selection of technologies affects environmental impacts. As a priority dry char discharge systems reduce waste water. Ankur Scientific Pvt. Ltd. (Vadodara, India) is developing a 'dry' gas clean-up system. Dry char discharge technologies remove the generation of black waste water arisings completely. It is strongly advised that future purchases of gasifiers invest in the dry gas clean-up system when available to avoid many of the environmental pollution problems discovered in this EIA.
- The **Rice Husk Char** (RHC) needs to be kept separate from the waste water streams to avoid sorption of metals or organic contaminants into the char.
- Application of RHC to land is beneficial at moderate application levels (up to 20 tonnes per hectare).

The results of the three studies were used as inputs to the Feasibility Assessment. The **Feasibility Assessment** shows that the technology and the project type are **eligible** for carbon finance as a standalone project under the Clean Development Mechanism (CDM) or Voluntary Gold Standard (VGS). However, it should be noted that the EU-Switch Asia proposal explicitly mentions that carbon finance is not part of the initial project, other than the present Feasibility Assessment. The EU-Switch Asia funding has the objective of installing 150 gasifiers explicitly without carbon finance. In order to demonstrate additionality of the project a clear decision needs to be made on what the role of carbon finance will be for. The study shows that carbon finance should be used to incentivize the implementation of adequate environmental management plans. In addition, the revenue could be used to improve affordability of gasifiers for millers (e.g. carbon finance is used to subsidize the purchase of rice husk gasification units), for the scale up of the project beyond the scope of the Waste to Energy project.

Preliminary Emission Reductions (ERs) calculations indicate an **average of 28,872.66 tCO_2/yr under the CDM scenario and an average of 30,348.17 tCO_2/yr under the VGS scenario**. At this stage, calculated ERs represent an estimation of the project potential due to the lack of coherent project design and dissemination plan.

The Financial Analysis shows that project technology can **generate emissions reductions at a level sufficient to cover the transaction costs of obtaining certification, although at present this is limited to the voluntary carbon market**. The analysis shows that the ER breakeven prices to cover transaction costs are relatively low compared to the market price for VGS but it is slightly higher than the market price for CDM. The analysis also shows the minimum size for a Voluntary Gold Standard project to breakeven should consist of a yearly average minimum of 32 Rice-husk gasification units. In order to generate surplus revenue a VGS project would need to consist of more than 32 units. Owing to the current low price of credits, the CDM option requires a yearly average minimum of 154 Rice-husk gasification units to cover the cost of accessing carbon finance. In order to generate surplus revenue a CDM project would need to consist of more than 154 units.

Using the existing project dissemination plan of 150 gasifiers over four years, two carbon finance routes (VGS and CDM), have been examined. There are pros and cons for each route to the market. Owing to the extremely low price per credit (€ 0.90/t CO_2) at the time of writing, there will be cumulative losses for CDM route throughout the seven year crediting period. However, there may be a price recovery or reduced regulatory risk. In this case the analysis may change but for the present time the CDM standalone route cannot be recommended.

In contrast, the VGS route is to generate net revenue from 2018 onwards. Despite the fact that demand for voluntary credits cannot be predicted, the relatively early and higher price of cash inflows render VGS to be the most attractive. Over the course of a seven year crediting period the project would generate net revenue in the region of €461K. This revenue is what would be available to the project proponent following the cessation of grants in 2015.

The present study has focused on the development of a CDM or VGS standalone project. However a third project scenario could provide a better alternative: Programme of Activities (PoA). The programmatic approach is interesting for the WtE project because it does not require a pre-determined number of project participants. This may suit the existing initiative which looks to establish the appropriate framework for a sustainable gasification sector. By registering the concept for converting waste to energy, individual millers would be able to join over time.

A follow up study on the feasibility of PoA for the rice-husk gasification sector in Cambodia is currently being carried out by Nexus-Carbon for Development. The objective is to develop a Conceptual Development Study and a Project Idea Note (PIN) to inform the development of a CDM PoA on rice husk gasification in Cambodia.

Attached to the present document the following **supporting documents** can be found:

- **Supporting Document I** - Gantt Charts for Validation and Verification of a standalone carbon projects
- **Supporting Document II** - Emission Reductions Calculations spreadsheet
- **Supporting Document III** - Project Idea Note (PIN)

Acronyms and Abbreviations

BETX	Benzene, ethylbenzene, toluene, meta + para xylene, orthoxylene
BOD	Biochemical Oxygen Demand
BRAF	Biochar Risk Assessment Framework
CDM	Clean Development Mechanism
CER	Certified Emissions Reductions
CME	Coordinating Managing Entity
COD	Chemical Oxygen Demand
CPA	Component Project Activity
DNA	Designated National Authority
DO	Dissolved Oxygen
DOE	Designated Operational Entity
Domrei	Domrei Research and Consulting
EB	UNFCCC Executive Board
EBC	European Biochar Certificate
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
ERs	Emission Reductions
FCRMA	Federation of Cambodian Rice Millers Association
IBi	International Biochar Initiative
LoA	Letter of Agreement
MPLs	Maximum Permissible Limits
N	Nitrogen
Nexus	Nexus-Carbon for Development
NOAA	National Oceanographic and Atmospheric Administration

P	Phosphorus
PAHs	Polycyclic Aromatic Hydrocarbons
SDWPC	Sub-Decree on Water Pollution Control
SQUIRTs	Screening Quick Reference Tables
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
VERs	Verified Emissions Reductions
VGS	Voluntary Gold Standard
VPoA	Voluntary Programme of Activities
PDD	Project Design Document
PIN	Project Idea Note
P/L	Profit Loss
PLN	Net Profit Loss
PoA	Programme of Activities
RHG	Rice Husk Gasification
RHC	Rice Husk Char
SNV	Stichting Nederlandse Vrijwilligers (Netherlands Development Organization)
UNFCCC	United Nations Convention Climate Change
WtE	Waste to Energy
§	Chapter
¶	Paragraph

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1. Introduction

This Report was prepared by Nexus-Carbon for Development (Nexus) within the ''Emission Reduction Project Baseline, Feasibility and Environmental Study for EU SWITCH-Asia Waste to Energy (WtE) for the Rice Milling Sector in Cambodia'' framework.

The report presents the work carried out by Nexus during the assignment period October 2012-February 2013. The work has been carried out in accordance with the service agreement ''Organization and Methodology: Services for and Emission Reduction Project Baseline/Feasibility and Environmental Study for EU SWITCH-Asia funded project entitled *Waste to Energy (WtE) for the Rice Milling Sector in Cambodia*, EuropeAid/130830/C/ACT/CAI''[1].

According to the service agreement[2] the key results from the study are the delivery of clear pathways towards:

- Carbon finance, along with suite of appropriate tools and
- Sustainable and environmentally-friendly integration of rice husk gasification technologies

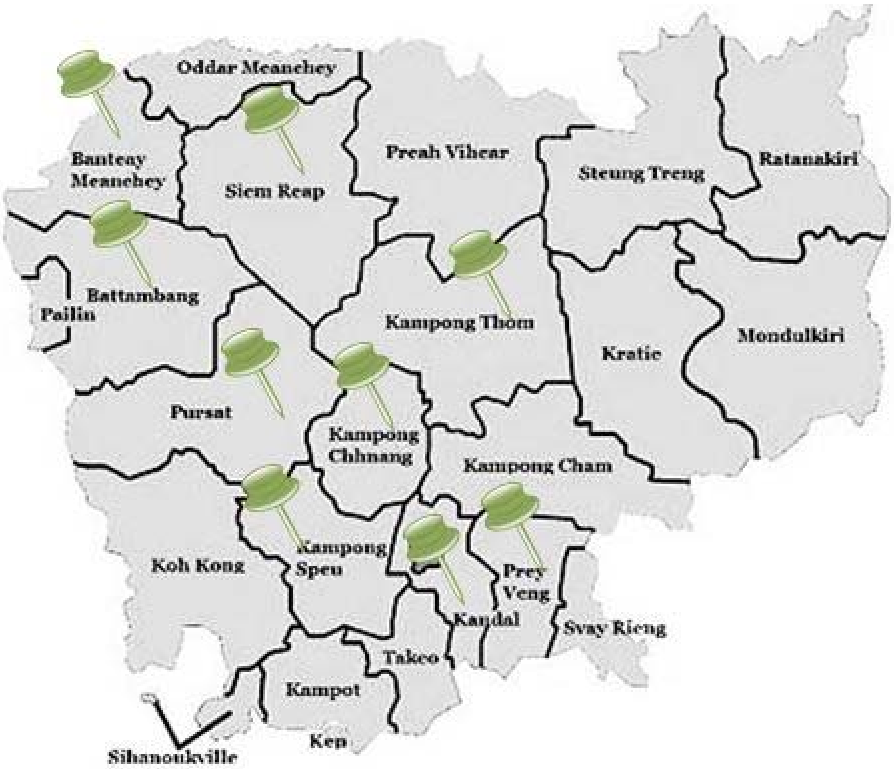

Figure 1: Administrative divisions of Cambodia

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[1] Bryan S., Chew S., Carter S. (2012) Organization and Methodology Services for Emission Reduction Project Baseline, Feasibility and Environmental Study for EU SWITCH-Asia funded project entitled ''Waste to Energy (WtE) for the Rice Milling Sector in Cambodia'', EuropAid/130830/C/ACT/CAI, Nexus-Carbon for Development.
[2] ibid 1;

Source: http://en.wikipedia.org/wiki/Administrative_divisions_of_Cambodia

The study focuses on nine target provinces that were indicated by SNV: Banteay MeanChey, Siem Reap, Battambang, Pursat, Kampong Cham, Prey Veng, Kandal, Kampong Speu and Kampong Thom.

The objectives outlined in the service agreement have been achieved through a systematic and comprehensive approach covering the following four work-streams:

1. Context analysis;
2. Baseline information study;
3. Feasibility study and
4. Environmental assessment including impacts and management plan

The Final Draft Report informs SNV and key stakeholders on: ***Approaches and Methodologies*** used during the course of the Study (§ 2); the ***Context*** presents the findings of the *Barrier Analysis* to renewable energy production and consumption in Cambodia as well as a *Review of Laws and Technical Standards* for waste management and other industries in Cambodia (§ 3); outcomes of the ***Baseline Study*** (§ 4), ***Feasibility Study*** (§ 5) and ***Environmental Impact Assessment*** (§ 6) are presented. ***Conclusions*** (§ 7) discusses identified opportunities, applicable mechanism and appropriate pathways to developing a rice-husk carbon project in the Kingdom of Cambodia. Recommendations and next steps are also presented.

Annexes at the end of the Report give full details on: CDM AMS.I.B Methodology (Annex 1), CDM Prior Consideration Form (Annex 2), Official Development Aid Declaration (Annex 3), Baseline Study Interviewee (Annex 4), Registration Completeness and Compliance Checklist (Annex 5), EIA: Key Parameters (Annex 6), EIA photograps (Annex 7), EMP Precedents in carbon projects (Annex 8).

This Report can be defined as the first concrete step towards the identification of a clear carbon finance route for the Milling Sector in Cambodia as well as to a sustainable and environmental-friendly integration of rice-husk gasification technology in Cambodia.

1.1. Project Team

During October 2012 a clear project team was assembled (Figure 2) by Nexus. The project team consists of Nexus staff with thorough expertise in Carbon Project Development: 1. Samuel Bryan, Nexus Technical Director, 2. Eleonora Gatti, Nexus Carbon Project Officer and external staff bringing valuable skills to team: 1. Dr. Simon Shackley - Rice-husk and Environmental Impact Assessment (EIA) expert, University of Edinburgh[3]; 2. Benjamin Lamberet - Agronomy and Environmental Engineer, Domrei; 3. Koeurn Saly - Field Supervisor and Translator, Domrei.

[3] http://www.geos.ed.ac.uk/homes/sshackle

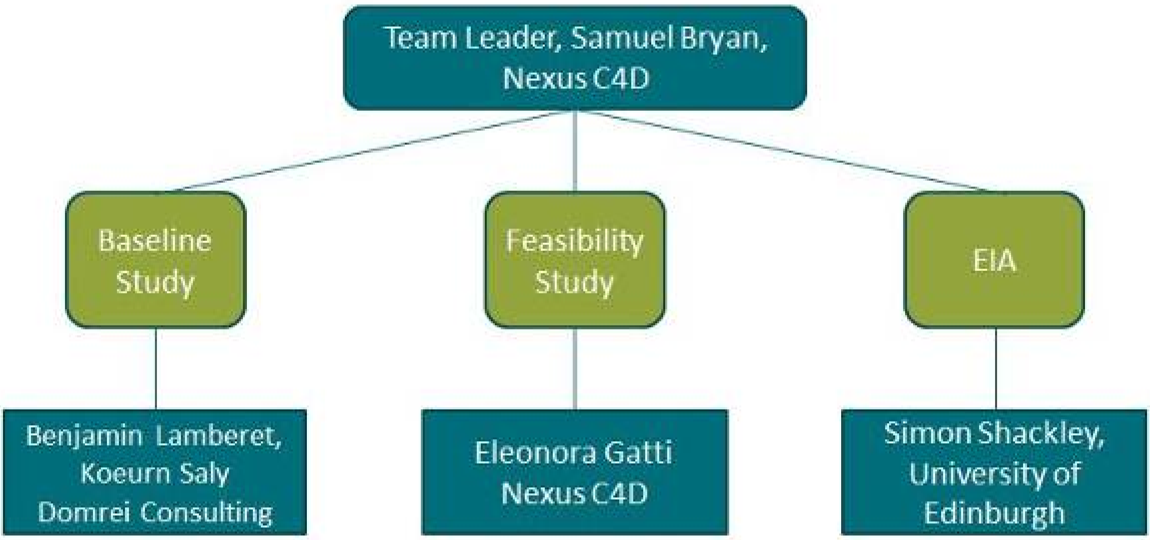

Figure 2: Project team organogram

1.2. Timeline of Activities

Nexus in cooperation with Dr Simon Shackley - Rice-husk Gasification and EIA expert, University of Edinburgh and Domrei Research and Consulting (Domrei) has concluded the first 6 activities of the Timeline of Activity[4] (Table 1).

Table 1: Timeline of activities

Description of Assignment	Timeline	Progress
1. Inception report including assignment schedule and work plan	November 2012	Completed
2. Presentation of methodologies/ tools and the edition of the methodologies/ tools for conducting the baseline	November - December 2012	Completed
3. Compilation study material and secondary data survey	December 2012	Completed
4. Conduct carbon baseline and environmental study – data collection, field survey, interviews	November 2012-January 2013	Completed
5. Data entry, screening and cleaning, and analysing, including roadmap design and gap analysis	December 2012-January 2013	Completed
6. First draft reporting	January 2013	Completed
7. Revising and editing, and final report submission	February 2013	Completed

[4] Organization and Methodology (2012) Services for Emission Reduction Project Baseline, Feasibility and Environmental Study for EU SWITCH-Asia funded project entitled ''Waste to Energy (WtE) for the Rice Milling Sector in Cambodia'', EuropAid/130830/C/ACT/CAI , Nexus-Carbon for Development, p 14.

2. Approaches and Methodologies

Chapter 2 *Approaches and Methodologies* presents the four study methodologies which have developed during the course of the study: 1. Context, 2. Baseline Study, 3. Feasibility Study, 4. Environmental Impact Assessment.

2.1. Methodological Approach: Context

Nexus with support from Domrei and Dr. Shackley carried out a Barrier Analysis with the aim of identifying potential institutional, legislative and regulatory and financial barriers to renewable energy (concentrating on waste to energy) production and consumption in Cambodia, with a focus on rice husk gasification.

Social, environmental and financial barriers to rice-husk gasification in Cambodia are assessed within six key areas:

1. Bioenergy production
2. Land use change & biomass resource
3. Land for food vs. energy production
4. Use of biodegradable wet waste
5. Use of biodegradable dry waste
6. Waste water management

The key actors taken into account during the Analysis are:

- The **Ministry of Industry, Mines and Energy** (MIME) – responsible for energy planning, policy and management;
- The **Electricity Authority of Cambodia** (EAC) – responsible for the regulation of both private and public suppliers of electricity, including the Electricité du Cambodge and issuing licenses to all operators. It approves all electricity tariffs and charges.
- The **Electricité du Cambodge** (EdC) – a government-owned power utility responsible for the generation, transmission and distribution of power in nine areas of the country;
- The **Ministry of Environment** (MoE) – responsible for reviewing and approving environmental assessments and environmental management plans of energy projects according to the requirements of the Law on Environmental Protection (NS/RKM/1296/36 dated 24/12/1996), and other relevant laws.

Both the Barrier Analysis and the Analysis of Law and Technical Standards have been carried out using a combination of primary and secondary data sources. Primary data include publicly available reports, texts of key Laws in the Kingdom of Cambodia as well as project documents of rice-husk carbon project in Cambodia. Secondary data sources include interviews with key staff at the CFRMA, 35 rice millers in 9 target provinces as well as international expert. [Full references are presented in § 3].

It is important to note that the rationale behind carrying out a Barrier Analysis during the preliminary phase of a carbon project is to inform the Feasibility Assessment of the project.

Understanding the nature of potential barriers to a carbon project ahead of the development of a clear project plan is crucial. According to Clean Development Mechanism (CDM) rules, the presence of barriers, i.e. financial barriers, is an essential pre-requisite to demonstrate that a project is additional and that carbon finance is required to develop it. [5] In contrast, the presence of barriers such as social barriers (e.g. the community living in the proximity of a project shows strong opposition to it) should inform project design.

2.2. Methodological Approach: Baseline Study

Baseline studies are a universal requirement for any type of carbon project.

In simple terms a baseline can be defined as a hypothetical reference case, representing the volume of greenhouse gases that would have been emitted if the project were not implemented.

Therefore, the baseline can be used to determine:

- Whether a CDM project activity is additional; and
- The volume of additional greenhouse gas emission reductions achieved by a project activity.[6]

Baseline Definition

The baseline for a [small-scale] CDM project activity is the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity (4/CMP.1, Annex II, paragraph 27).

With reference to a general rice-husk carbon project - where rice husk is used to produce mechanical energy for the mill - the simplified baseline is the estimated emissions due to serving the same load with a diesel generator consumption saved times the emission coefficient for diesel. The diesel emissions displaced annually are calculated either as:

- The power requirements times hours of operation per year times the emission factor for diesel generator systems;
  or
- The diesel fuel consumption per hour times hours of operation per year times the default value for the emission coefficient for diesel fuel (3.2 kg CO_2 per kg of diesel fuel).[7]

Under business-as-usual circumstances, rice mills in Cambodia are often not connected to the grid. Diesel is used to produce on-site mechanical energy to run the mill. This constitutes the Baseline Scenario. Instead the installation of a rice-husk gasifier has the potential reduce diesel fuel consumption compared to the business-as-usual scenario. This constitutes the Project Scenario.

To be able to quantify the baseline a baseline survey methodology and corresponding baseline questionnaire need to be designed. Nexus in cooperation with Domrei developed a baseline survey methodology and questionnaire.

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[5] CDM Rule Book, [Online] Available at http://cdmrulebook.org/166
[6] CDM Rule Book, [Online] Available at http://cdmrulebook.org/164
[7] CDM Methodology AMS.I.B Version 10 *Mechanical energy for the user with or without electrical energy* [Online] Available at http://cdm.unfccc.int/methodologies/DB/5TDWYSV5EYM4332XSOUT4EV8XHT03G

2.2.1. Baseline methodology: sampling

This section gives an overview of the baseline sampling methods, survey design as well as field work plan, data processing and analysis.

Interviews with 30 rice millers without gasification technology is the primary source of information for the baseline study. 5 interviews with rice millers with gasification systems was also be conducted across 9 target provinces in Cambodia (Table 2 and Annex 4). Data collected with the baseline survey was cross-checked with interviews with key informants: e.g. Federation of Cambodian Rice Millers Associations (FCRMA), gasifier manufacturers in Cambodia, SNV.

In order to capture sufficient information to develop detailed emission reductions calculations and to produce meaningful results for any subsequent validation by an external auditor (Designated Operational Entity), Nexus worked in cooperation with Domrei during Baseline Study Phase. Domrei has more than 10 years of experience in conducting Survey in Cambodia on behalf on international organizations and key development agencies such as UN, World Bank, Asian Development Bank, Path, etc.[8]

Table 2: Baseline survey sample

Respondents (n)	Gasification system	Province
30	No	• Banteay Meanchey • Battambang • Kampong Cham • Kampong Speu • Kampong Thom • Kandal • Prey Veng • Siem Reap
5	Yes	• Battambang • Kampong Cham • Siem Reap

The final sample [Margin error: 0.15, Confidence Level: 90%, Sample size: 30, Completed Interviews: 30, Response rate: 100%] was drawn from the overall defined target audience of mills provided by SNV (179 rice millers in total: 30 with WtE technology, 149 without WtE technology). 30 mills without gasification technology were randomly selected as a representative sample of the total population. Random sampling strategy was deemed the most appropriate strategy as in compliance with ''General Guidelines for Sampling and Surveys for Small Scale CDM project activities''[9]. Given that in the suitable methodology for this type of carbon project AMS.I.B[10] does not provide specific guidance on minimum level of confidence and precision, the 90/10 confidence/precision level is being used as per ''General Guidelines''. In addition, a convenience sample of 5 mills with gasification technology was selected. Three criteria were taken into consideration to draw the final sample:

1. Milling capacity > 1t/hr

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[8] http://domreiresearch.com/experience
[9] http://cdm.unfccc.int/Reference/Guidclarif/ssc/methSSC_guid20.pdf
[10] http://cdm.unfccc.int/methodologies/SSCmethodologies/approved

2. Annual operation > 4 months[11]
3. Mill has to be still in production

All the selected mills fall within the 9 target provinces of Banteay MeanChey, Siem Reap, Battambang, Pursat, Kampong Cham, Prey Veng, Kandal, Kampong Speu and Kampong Thom.

The convenience sample of mills with gasification technology was drawn so to have variation in the type of gasification technology used - imported technology as well as local copy-cats.

Final baseline sample can be accessed in Appendix 4.

2.2.2. Baseline methodology: survey design

During the Inception Phase Nexus in cooperation with Domrei and Dr. Simon Shackely gathered background information on the rice milling sector in Cambodia, gasification technology as well as rice husks disposal and potential environmental impact of gasification systems.

Background information was used to develop a comprehensive baseline survey. The questionnaire includes open-ended questions as well as pre-coded questions. The answers given provide essential data for the Feasibility Study and the Environmental Impact Assessment which follow the baseline survey. The aim of the baseline survey is to collect information in the following key areas:

- Annual fuel/energy use by rice millers
- Energy carrier –e.g. diesel- / grid connection
- Rice processing capacity
- Seasonal variation impact on milling activities
- Practice for disposal of rice husk
- Perception of gasification
- Existing waste water treatment plants
- Record keeping and data management practices

The final baseline survey instruments consist of two questionnaires:

1st questionnaire for the mills without gasifier; this questionnaire is composed of 5 sections collecting information on:

- The mill characteristics
- The milling activity/process
- Focus on the Rice Husks Disposals & the Gasification Alternative
- Energy consumption
- Data Collection, Record Keeping and Data Management

2nd questionnaire for mills with gasifier. Two more sections have been added:

- The mill characteristics
- The milling activity/process
- Focus on the Rice Husks Disposals & the Gasification Alternative
- Energy consumption
- Gasifier characteristics

[11] Out of the final sample without gasification technology, 20 mills have annual operation of 7 months. One third has operation of 5 or 6 months.

- Environmental and Health Issues
- Data Collection, Record Keeping and Data Management

The questionnaire includes open-ended questions, pre-coded questions as well as an introduction summarizing aim of the overall Waste to Energy Project and project logos.

Data collected during Baseline Survey provide essential data for the Feasibility Study and the Environmental Impact Assessment. Collection of reliable and accurate data depends on the accuracy of the questionnaire. The instrument is designed both in English and Khmer languages. Only the Khmer version was used during interviews.

3 pre-tests were conducted by Domrei Field Supervisor in Kandal and Kampong Cham provinces to ensure that the questions are easy to understand and appropriate, as well as to assess the functionality of the questionnaire, including skipping patterns. Results from the pre-tests have improved the quality of the questionnaire. 6 versions of the questionnaire were produced in total. Comprehensive feedback received from SNV during the Inception Meeting was duly incorporated in the final version.

2.2.3. Baseline methodology: data collection and analysis

Before the fieldwork, recruitment and training has strengthened competency of the interviewers and their ability to realize a high quality field survey. The Pilot Field Test is then the last step for the instrument to be approved.

Recruitment started on the 23rd of November. Only highly experienced, autonomous and reliable staff was hired for the project. A total of 5 staff has been hired by Domrei.

Training for the interviewers lasted for 3 days[12]. Staff received extensive training to ensure their knowledge about the milling activity and the gasification technology, data collection and interview techniques. Evidence of the training is available upon request.

The instrument's final testing, which took place on the December 1st, allowed further modifications and improvements to be incorporated in in the final version of the questionnaire.

The field work took place from December 5th to December 9th. Mr. Saly Koeurn, Field Supervisor, coordinated the team work. Each staff interviewed 5 mills without gasifier and 1 mill with gasifier. Each staff conducted the interview with the mill owner/manager, following the different sections of the questionnaire. Interviews were carried out at the private house of millers or at the main office in the mill. To ensure that the miller understands perfectly the questions, few sections of the questionnaire were tackled during the mill factory and gasifier installation visit. Photos were also taken in order to point out the most important problems related to the gasifier wastes (char, tars, waste waters, etc.) and to give an overview of the proposed management solutions.

Following the field work Domrei data manager supervised data entry process as well as data cleaning and verification. Data was then entered into the custom-designed data entry program, validated and verified for quality.

[12] November 30th, December 1st and 3rd.

Domrei conducts double data entry for all surveys, to ensure consistent and accurate data. After the data is entered twice, the two data sets are compared to create an error report. The data is then "cleaned" to check for inconsistent answers and incomplete data using Microsoft Access and the original paper questionnaires. Random checks of the data entry process and database were undertaken. Using commands and algorithms in Microsoft Access, the dataset was checked for duplicate unit entries. Logical edit checks were performed to ensure that variable data values linked to each other are consistent. Consistency edits to check that a precise and correct arithmetic relationship exists between two or more variables was also be carried out together with range edits to ensure that data values adhere to editing rules and specifications. The data set was also checked for erroneous outliers through variance edits.

Following the data cleaning, the data manager run the analysis and tabulations using Stata program. Results from the Baseline Study are presented in Chapter 4.

2.2.4. Baseline study timeline

Table 3 presents the Baseline study timeline.

Table 3: Baseline study timeline

Baseline Study Timeline	November				December		
	5/11	12/11	19/11	26/11	3/12	10/12	17/12
Baseline Survey: WtE for the Rice Milling sector in Cambodia							
Planning and Design							
Survey Planning/Field Plan							
Instrument design/translation/adaptation							
Instrument pre-testing							
Data entry							
Data Collection							
Recruitment							
Training							
Pilot Field Test							
Field Work							
Data Analysis							
Data entry (First and second)							
Data Cleaning							
Clean Dataset (SPSS)							
Final Database and Data Delivery Report							
Baseline Report							
Draft Report							
Final Report							

2.3. Methodological Approach: Feasibility Study

Ahead of the development of any type of carbon projects a Feasibility Study needs to be conducted. Nexus followed a standardized Feasibility Study methodology based on UNFCC Executive Board Registration Completeness and Compliance Checklist.[13]

The key steps of a Feasibility Study are as follows:

1. Eligibility Assessment;
2. Preliminary Emission Reduction Calculations;
3. Financial Analysis of the Project;
4. Gap Analysis;
5. Roadmap;
6. Project Idea Note;

Requirements within the six areas above mentioned for CDM and Voluntary Gold Standard carbon projects have been respectively taken from CDM Rule book[14] and Gold Standard manuals[15].

2.4. Methodological Approach: Environmental Impact Assessment

Wastes are generated during rice husk gasification, some of which might result in contamination and pollution. The major emission streams are the gaseous, solid and liquid waste streams. Gasification typically produces <10% solids by mass (char) and very small amounts of liquid (a few percent), with the majority of the biomass feedstock being converted into synthesis gas for use in an engine or turbine. Gasification of rice husks is somewhat different, however, due to the very high silica content of the rice husk which is not broken down at gasification temperatures (having a higher melting point than gasification temperature). Hence, the solid residue of rice husk gasification is c. 30%.[16] The high yield of rice husk char (RHC) means that such material may become a disposal problem (Figures 16, 42).

Provided that the gasifiers are using rice husks, the major environmental issues for the gasifiers are the solid and liquid waste streams. Because rice husks are a by-product of paddy rice production, their production does not raise any land-use change issues additional to the rice production itself. Issues such as loss of biodiversity and 'carbon debt' arising from direct and indirect land-use change do not need investigating as long as agri-residues are used which are not otherwise being used to the extent that their use as a fuel for gasification would require substituting another material for rice husks in other applications (which could thereby incur additional CO_{2e} emissions).

And because the value of the rice dominates the system, there is very little chance that rice husk production would be the main driver for establishment. If feedstocks other than surplus agri-residues are used, the impacts on direct and indirect land-use change (LUC/ILUC) would need to be

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[13] see Annex 5.
[14] http://www.cdmrulebook.org/home
[15] http://www.cdmgoldstandard.org/project-certification/rules-and-toolkit
[16] Shackley, S. et al. (2012), 'Sustainable gasification-biochar systems? A case-study of rice-husk gasification in Cambodia: Part I: Context, chemical properties, environmental and health and safety issues', *Energy Policy* 42: 49-58.

considered. For instance, if trees were felled to provide wood for a gasifier, this could have deleterious effects on biodiversity and add to atmospheric CO_2 emissions, depending on re-planting and sustainable forestry management. LUC/ILUC is context-specific and needs to evaluate on a case-by-case basis. Where this is not possible, however, there are some generic factors than can be utilized to estimate net greenhouse gas contribution from land-use change for biofuel production, though they are not currently reliable in a quantitative sense.

2.4.1. Gaseous emissions

The gaseous emissions are fugitive emissions arising from less than perfect seals and leaky pipes and fittings. The syngas may leak at various stages of the operation from the main reactor to the three or four filter tanks or from pipes in between. Anecdotal evidence was obtained during field work that some workers feeding the top of the reactor felt 'dizzy' and 'nauseous'. This might indicate escape of gases such as carbon monoxide. To measure such fugitive emissions requires use of very specific and expensive equipment and this was not available to the project team. We did not explore gaseous emissions further therefore. A follow-on study that factors in the hiring and appropriate deployment of equipment which can measure fugitive gaseous emissions can be considered.

2.4.2. Waste water

Water is used to quench the hot gases as they exit from the reactor and strips out tars from these gases. In the Ankur wet-discharge model, the same waste water is used to quench and remove the hot char from the bottom of the reactor. A dry-char discharge model is available from Ankur Scientific, which does not mix the waste water from the tar stripper with the char. The RHC is instead removed from the base of the reactor with a screw augur that deposits the RHC several meters from the reactor and allows it to be bagged-up for removal. The dry-char discharge design means that the RHC does not absorb contaminants that are present in the black waste water stream; hence the RHC is likely to be more consistent and cleaner.

The first Ankur dry-char discharge models are being installed in Cambodia and sampling was undertaken from one such facility (gasifier number 4). In other designs, e.g. Chanrorn, the waste water from the gas cleaner forms a separate waste stream from the water that is used to remove the char from the base of the reactor (e.g. gasifier number 7). However, the two waste streams are then combined in the settling pond.

The typical gasifier design transports the black water waste stream by pipe to a settling pond (SP) or tank just outside the housing of the reactor (Figure 19, 35). There are frequently 2 to 4 settling ponds constructed of concrete and lying in sequence and typically 1.2 to 1.5 meters deep and 3 - 4 meters long and wide. The hot waste water cools in these ponds and in many cases the water is pumped through a shower device from which it sprays out of a series of nozels to speed-up cooling. The water is then pumped back to the gasifier where it is again used for gas scrubbing and char removal. In every case observed, there is seepage of black waste water into the local environment. This typically occurs as a result of the settling tanks over-flowing (figure 40). However, in many cases, it appears that a certain volume of water is discharged routinely and intentionally, in one case at a rate of a few litres per minute (figure 43). The waste water is changed every one week to ten days, the water being disposed of to the local environment.

A sludge forms at the bottom of the settling tanks (figure 17). This sludge consists of RHC, some broken down into very small particles. It may also contain tarry residues. The sludge should be removed from the bottom of the settling pond once every month, after which it will have formed a 30cm deep layer (depending on the load factor and properties of the rice husk). When removed, the sludge is typically disposed of in local fields or added to the RHC piles.

Most gasifiers are located in low-lying areas where the water table is close to the surface, especially during the wet season, during which time many fields in the delta regions of the Tonle Sap Lake and river and of the Mekong and its tributaries become marshy or even swampy fields. The sampling was undertaken during the dry season (early January 2013) and the land surrounding the gasifier installations was dry to marshy. Because of the very flat topography, waste water streams tend to flow into (and contribute towards) marshy areas surrounding the facility (figure 45). In a number of cases, the waste water flows directly into a disposal pond (DP) (figures 34, 39). Such ponds appear to have been dug for this purpose (e.g. sites 1, 4), while in other cases the waste water from the gasifier ended up in a disposal pond into which other types of waste were deposited (e.g. toilet waste from the garment factory, 2).

In yet other cases, waste water was dispersed by streams (figures 44 and 47) and ended-up in a pond outside the facility boundary (e.g. 9). It was not always possible to gain access to the final disposal pond of the waste water (e.g. 3, 7). In two instances (4 and 9), ponds were identified close to the facility but into which the black waste water did not appear to be entering. In the case of 4, this pond showed evidence of clean water, notably good clarity, healthy-looking water lilies on the surface and plenty of insect and animal life (notably frogs) on the surface and within the water itself (figure 41). In the case of 9, there were two 'clean' ponds, one close to the mill but not receiving black water waste, and another close to the final disposal pond, but which showed evidence of eutrophication, with an extensive algal bloom (figure 46). These three ponds constitute two useful 'baseline' situations – two clean (CP) and one suffering from eutrophication (EP).

The key environmental impact issues arising from the waste water streams are as follows:

- Risk of contaminating drinking water with metals and / or organic contaminants, e.g. by accumulation of contaminants in low-lying ground and dispersion and seepage into the water table, so effecting water extracted for drinking.
- Risk of causing ecological damage in hydrological and associated ecological systems – e.g. in marshy, swamp areas; in streams; in ponds.
- Risk of contaminating soil (with attendant risks for food production and future uses of that land).
- Risk of long-term liability associated with the sites due to persistence of heavy metals and some organic pollutants.

2.4.3. Waste Water Discharge Standards

Gasification units and rice mills are subject to the controls imposed by the ***Sub-Decree on Water Pollution Control*** (SDWPC) enacted in 1999 by the Council of Ministers which aims to control waste water discharges in order to maintain water quality (see section 3.1.). The SDWPC provides maximum permissible limits (MPLs) for a range of chemical species and other environmental indicators. Two quality levels are provided, one for water discharge into protected water bodies with lower MPLs and the other for water discharge into non-protected water bodies and sewers, with higher MPLs. The drinking water standards of the CDWQS function as the most stringent measure of water quality. Hence the standards for discharge into a non-protected public water way or sewer is the minimum that waste water should meet while the drinking water standards represent a high level of environmental protection.

Waste water was collected at each site from the settling pond (SPWW) and, where relevant, from the waste disposal stream and pond (DSWW, DPWW) (figure 45). Several adjourning ponds not receiving waste water (e.g. CP, EP) were also sampled (figure 40, 46). The method in each case was to insert the collection vessel and fill to the specified volume.

A number of samples were sent to two laboratories in Cambodia – Resource Development International Cambodia (RDI-C), which undertook measurement of biological and chemical oxygen demand (BOC, COD) as well as metals, oil and grease and total suspended solids (TSS) and total dissolved solids (TDS). BOC and COD have to be measured within 48 hours of collection. The Industrial Laboratory Centre of Cambodia (ILCC) also undertook measurements of metals, oil and grease, TSS and TDS. The remaining samples were analysed by Northumberland Water Scientific Services (NWSS), which has the capability to measure complex organic molecules (not currently available in Cambodia).

In situ measurement of the pH, temperature, dissolved oxygen and electrical conductivity (EC) of the waste water in the settling ponds, disposal ponds, adjacent ponds and streams was undertaken at the nine sites where feasible. A multi-probe hand-held Hach instrument was used for this purpose (figure 34, 35).

See Annex 6 for details on key Parameters for testing in waste water, sludges, soils and rice husk char (table 60) and identity of key toxic and / or Persistent Organic Pollutants (table 61).

2.4.4. Sludges

As already noted the waste water quenches and removes the hot char from the reactor and is then piped to a cooling pond where a shower system may be used for cooling, after which the water is re-introduced into the hot gas stripper and the cycle starts over again. Sludges collect in the bottom of the cooling pond as muddy sediment, presumably arising from rice husk char (whole and fragments), ash and dust produced in the gasifier, metals from the reactor, and so on. These sludges need to be removed periodically (monthly) to avoid excessive siltation and reduction of the volume of the cooling pond. It is normal practice to dry sludges and then to dispose of in local fields or to add them to the rice husk char (RHC) piles. Addition of sludges directly to land, or via RHC, could introduce contaminants in sludge to soil and into the ecosystem and/or the food chain.

One sludge sample already analysed (see Table 55) appears to contain high amounts of phenolic compounds, benzene-type compounds and polycyclic aromatic hydrocarbons (PAHs), all of which raise health and environmental pollution issues. Nine more sludge samples have now been tested to confirm the presence and concentration of such contaminants in sludge and to examine whether their levels vary according to gasifier reactor design. If confirmed, the sludges need to be treated as a special waste and disposed of appropriately.

2.4.5. Rice husk char (RHC)

The amount of carbon conserved from the feedstock into the solid residue during rice husk gasification is approximately 10% by mass, higher than woody feedstock gasification (where it is typically a few percent by mass) (Shackley et al., 2012). It is not known why 10% of carbon is conserved since at gasification temperatures, the majority of the carbon should be oxidised to CO_2. It may be a consequence of a weak chemical bond between plant carbon and the silica shell.

A reasonable number of samples of RHC from Ankur gasifiers in Cambodia (8 in total) have already been tested for potential toxic elements (PTEs) and persistent organic pollutants (POPs) and the data is available to the project (presented in Table 61) (and is reported in Shackley et al., 2012). That data indicates that RHC is a clean material and safe to use in moderate levels in agricultural soils, provided that it is not contaminated with other solid or liquid wastes, such as sludges or black waste waters. As yet, there is no data on the RHC arising from the alternative designs to Ankur's. Due to resource limitations, it was not possible to conduct any further testing of RHC here.

2.4.6. Tars

Three to four gas cloth and sand dust filters are used to clean-up the syngas after it has emerged out of the gas scrubber (figure 18). Tar drips out of the base of each filter. The tar is sometimes burnt and sometimes just deposited in the local environment. Two tar samples were collected and tested for potential organic contaminants.

2.4.7. Sampling methodology: selection of the gasifiers from which sampling was undertaken

The selection of gasifiers from which to sample was determined by the following issues: a) the practicality and logistics of visiting and taking and transporting samples; b) the limited budget available for laboratory analysis of the samples collected; c) inclusion of a sufficient number of different gasifier designs and models; d) inclusion of gasifiers from a range of major rice-producing and processing locations in Cambodia; and (e) inclusion of gasifiers which are known to be operated and maintained in an exemplary fashion as well as ones known to be operated and maintained in a sub-optimal way and a few reactors 'in the middle'.

The sample that was selected is shown in Table 5. Three provinces were included: Kandal, Siem Reap and Battambang. It was felt that these three provinces were reasonably representative of the country as a whole, including major rice growing provinces which broadly reflect the growing conditions in Cambodia, including topography. Three gasifier manufacturers were included: 6 from Ankur as the sector-leading manufacturer, with approximately 40 gasifiers installed in Cambodia and offering a relatively expensive machine (c > $90k) ; 2 from Chanrorn, the leading alternative and predominant Khmer manufacturer, costing approximately half that of Ankur) (i.e. c. > $40K); and one from Seng Kuch, a cheaper gasifier (<$20,000). Note that Ankur gasifiers are manufactured in India and imported unlike Chanron and Seng Kuch, which are manufactured in Cambodia. This increases the cost of Ankur machines due to importation costs; hence price is not necessarily indicative of quality. It was important to include a few alternative gasifier designs in the study in order to allow a comparison of the environmental performance of different designs, though with such a small sample, there is a strong likelihood that the performance is as much related to operation and maintenance as it is to design.

The full set of samples tested is indicated in Table 4 and 5 below.

2.4.8. Waste water treatment system at gasifier number 4

Gasifier 4 is an especially interesting case because it is the first village-scale micro-grid project that is using rice husks for electricity generation in Cambodia. Furthermore, the gasifier installed includes a dry char discharge system (so reducing the amount of pollutant which might enter the waste water stream) and also a dirty waste water clean-up system developed by Ankur Scientific Pvt. Ltd. (figure 37). Sampling from 4 allows a comparison to be made of the effectiveness of this waste water treatment system. The waste water treatment system uses three filters which remove most of the particles and contaminants from the waste water. The first stage is an alum coagulation unit which removes the larger particles from the liquid. The waste water then passes through sand and charcoal filters and emits as a clear clean water. The only waste water treatment system currently operating in Cambodia is the REE gasifier. We were able to sample from the unit. The waste water treatment system only handles approximately 15% of the waste water generated. Hence, while the treated water appeared to be clean (figure 38), there was evidence of considerable amounts of black waste water entering the disposal pond (figure 39, 40).

Table 4: Sampling regime at five RHG

Media	Water	Sludges	Char	Tar
Gasifier 1	3	2		1
Gasifier 2	1			
Gasifier 3	2	1		1
Gasifier 4	4	2		
Gasifier 5	3	1		
Gasifier 6	2	1		
Gasifier 7	1	1		
Gasifier 8	1	1		
Gasifier 9	4			
Total	21	9	4	2
Existing sample analysis	2	1	8	
Grand Total	23	10	12	2

Table 5: List of gasifiers sampled[17]

Site Number	Province	Gasifier Manufacturer & Model	Samples tested
1	Kandal	Ankur FBG200	6
2	Kandal	Ankur Combo 350 kW	1
3	Kandal	Seng Kuch	4
4	Siem Reap	Ankur [18]	6
5	Siem Reap	Chanrorn	6
6	Siem Reap	Ankur FBG150	3
7	Battambang	Chanrorn	2
8	Battambang	Ankur	2
9	Battambang	Ankur FBG200	4

2.4.9. EIA timeline

Table 6 presents Environmental Impact Assessment Study timeline.

Table 6: EIA timeline

EIA Timeline	November				December					January		February		
	12/11	19/11	26/11	3/12	10/12	17/12	24/12	31/12	7/1	14/1	21/1	28/1	04/02	11/02
Planning and Design														
preparation of the barriers document for the IR														
design of the EIA survey parameters and methodology														

[18] Dry char discharge and with waste water treatment system installed.

identification of key laboratories capable of providing necessary analytical services														
Data Collection														
organise visits to five gasifiers														
assemble sampling equipment and devices														
sampling period in field														
samples sent to testing laboratories														
Data Analysis														
laboratory data analysed														
EIA based upon lab analysis and observations in field work														
follow-up information gathering and expert questions and to OEM														
Reporting														
Draft Report														
Final Report														

3. Context

This section presents the Barrier Analysis and the Analysis of Laws and Technical Standards.

The Barrier Analysis (¶ 3.1) examines the institutional, legislative and regulatory barriers to renewable energy production and consumption in Cambodia, with a focus on waste to energy and rice-husk.

The Analysis of Laws and Technical Standards (¶ 3.2) highlights existing laws and technical standards for waste management in Cambodia, with a focus on rice-husk.

3.1. Barrier Analysis

Bioenergy Production: biomass is an important source of energy for the majority of Cambodian families as well as small scale industries both in rural and urban areas (garment, brick kilns, rice mills, rubber production, food industry and ice factories). The use of biomass in the industry sector in Cambodia can play a key role towards achieving 25% of energy savings by 2030. [19]. Despite the fact that many policies have been adopted and many projects have been developed in the realm of bioenergy production, no clear legislative and regulatory framework exists in Cambodia. There is therefore no legal barriers *stricto sensu* to the bioenergy production. However other types of barriers can be identified:

- Technical barriers due to the limited skills and knowledge to comply with standards and technical specification of technologies in use. Technical assistance from the international community is therefore needed[20];
- Economic barriers due to the fact that very often energy efficient technologies are more expensive than the traditional ones and require an higher upfront investment; however, the contract signed between GE Energy and Soma Group in July 2012, for the establishment of a biomass gasification power facility, gave birth to the first biomass tariff provided by the government, and may encourage the wider development of such technologies in Cambodia in the future[21];
- Social barriers: sometimes the introduction of new technology, especially if it is imported from other countries and dissimilar to local technology clashes with Cambodian culture and habits, thus imping on the technology dissemination.[22]

Land Use Changes & Biomass Resource: apart from the Law on Concessions[23] which requires a Business Plan/Concession contract for any new industrial concession, no legal/regulatory barrier

[19] Baskoro, I (2012) *Biomass Energy Production & Consumption*, Presentation at European Union Energy Initiative, Inception Workshop on Development of a national Energy Efficiency Policy, Strategies and Action Plan, Phnom Penh, November 22-23;

[20] Refer to Chapter 4 Results: Baseline Study.

[21] http://www.ge-asean.com/ecomagination/soma-group-chooses-ge-waukesha-gas-engines-for-rice-husk-biomass-energy-project

[22] Baskoro, I (2012) *Biomass Energy Production & Consumption*, Presentation at European Union Energy Initiative, Inception Workshop on Development of a national Energy Efficiency Policy, Strategies and Action Plan, Phnom Penh, November 22-23;

[23] Law on Concession (Ministry of Land Management, Urban Planning and Construction, 2007), English version available online:

exists in Cambodia for land use management. Barriers related to land use change & biomass resource availability identified during the analysis were as follows:

- Weak environment protection management and enforcement capacity: deforestation and degraded woodland wide spread in the provinces of Cambodia (e.g. Kampong Cham), due to the extraction of wood for charcoal production. Moreover, the majority of charcoal kilns are traditional and inefficient. Programs for more sustainable charcoal production are underway (UNDP, EEP and GERES[24]) and a more sustainable management of wood resource for charcoal production is needed;
- Low government capacity to implement MoE programs: lack of internal consistent policy, law, regulation because of the multiplicity of Authorities, and overlapping mandates[25].

***Land for Food vs. Energy Production*:** At the present time, the in-country market demand for crop biofuel feedstocks – which could serve as human or animal food, such as maize, soybean and cassava - is not yet causing a threat to food security as conversion of land from rice production to biofuel feedstock crop production is not observed to be taking place. Income from rice farming is still competitive with, or even better than, that which farmers get from biofuel feedstocks, so, in this scenario, there is no added incentive or advantage for farmers to plant biofuel feedstocks instead of rice[26]. Both smallholder farmers and the government have given priority to sustaining and expanding rice production to meet rising consumption needs in the face of rapid population. Given uncertainties in future fossil fuel prices, improvements in biomass processing and government priorities & incentives, it is possible that biofuel production could become more profitable in Cambodia than rice production in the not too distant future[27]**.** Finally, no barrier has been identified yet, but the situation could change as the demand evolves fast, so an evaluation framework would be required (e.g. with FAO participation).

We can distinguish between wet and dry wastes. Wet wastes can be processed using anaerobic digestion or composting, while dry wastes are better processed using combustion, gasification or pyrolysis. This report focuses on Anaerobic Digestion for the wet wastes and Gasification for the dry wastes.

***Use of Biodegradable Wet Wastes in Cambodia*:** The *National Biodigester Program* (Ministry of Agriculture, Forestry and Fishery in cooperation with SNV Netherlands Development Organization[28]) proposes the solution of Anaerobic Digestion of Wet Biodegradable Wastes for biogas production.
Two large microfinance Institutions (MFIs), PRASAC and AMRET, are providing special loans to farmers to help them afford biogas plants. Finance does thus not seem to constitute a barrier.
Comprehensive quality standards and a quality control system are in place, while extensive promotion materials are available and disseminated at national, sub-national and grassroots levels, which contribute to the incentive effort for this programme.
Once again, no major legislative or regulatory barrier can be found for the use of biodegradable wet wastes in Cambodia. However, other barriers can be identified: 1. technical barriers: the lack of

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http://www.cambodiainvestment.gov.kh/content/uploads/2011/09/Law-on-Concessions-Full-Text_071019.pdf

[24] http://www.cambodia.geres.eu/our_projects/sustainable_charcoal

[25] ICEM, 2003. *Lessons learned in Cambodia, Lao PDR, Thailand and Vietnam*. Review of Protected Areas and Development in the Lower Mekong River Region, Indooroopilly, Queensland, Australia, p25.

[26] *Bioenergy and Food Security: the BEFS analysis for Thailand*, Environment and Natural Resources Management Working Paper 42, FAO, Rome (Mirella Salvatore and Beau Damen, 2010)

[27] ADB TA7833 is undertaking case-studies of food vs. bioenergy with Cambodian government;

[28] http://www.nbp.org.kh/

trained masons to build AD digesters and the lack of staff to implement even further the NBD program are restrictions to its wider development (more digesters could be built and more loans & subsidies could be applied for)[29]; moreover anaerobic digestion is efficient only at small scale, like rural household scale (with livestock, etc.); 2. environmental barriers: deployment in some areas is prone to flooding problems (yet floating designs are possible, for example with Live and Learn Environmental Education projects[30]).

***Use of Biodegradable Dry Wastes in Cambodia*:** Rice straws and rice husks are the two main dry biodegradable wastes.

Rice straws can be used in many different ways: cattle fodder, fuel, building material, etc. The main barrier for the use of rice straws is linked to their silica (Si) concentration: the high Si content makes them difficult to process (i.e. to burn or use them in a gasifie). Moreover, important time and effort are needed to extract straws from the field, so on-site burning is still widespread, even if forbidden.

Rice husks (hulls) are an increasingly important resource and by-product of the rice production. Rice husks can be used for heat production (e.g. into fire brick kilns) or to produce syngas via a down-draft gasifier. The gas is fed into an engine for electricity or motive power. In other countries (Thailand, India), rice husks are burnt in larger combustion units to raise steam, which is used to power a turbine for electricity generation, fed into the grid.

In Cambodia, the deployment in the private sector led on purely commercial grounds with no subsidies, though some favourable loans from turnkey contractors (e.g. SME Renewables) have appeared recently.

Even if a detailed construction plan of the gasifier is required by the local Authority Planning Department and the Provincial Department of the Environment to grant the installation, we cannot identify any major legislative or regulatory barrier. While there are no obvious institutional barriers, i.e. in the sense that the institutions of the local or national government are unlikely to prevent development of a commercial gasifier, the lack of a clear bioenergy policy means that there are not incentives for renewable energy generation. Many countries have now embraced Feed-in-Tariffs (FiTs) or other renewable energy incentives or obligations (ROCs) on power producers. Independent power products (IPPs) need to be connected-up to the electricity grid in order to be able to benefit from FITs or ROCs. Part of the economic rationale for gasification installation to date has been the off-grid nature of rice mills and ice factories, so if a mill were connected to the electricity grid, it is unclear whether gasification installation would automatically be selected over buying in grid-electricity. However, as seen before, the contract signed between GE Energy and Soma Group in July 2012 appears to be the first biomass tariff provided by the government.

Gasification works well at the small-scale of a micro-gasification stove all the way up to about 1MW and, potentially, much larger, though most commercial efforts at scales beyond a few MW have not been successful to date (it is preferable to use steam turbine systems at large scales).

Gasification is easy to adapt for a mill or an ice making factory, but difficult at the scale of the village: SME Renewables did pilot a gasifier at the village-scale in 2006 but found that there was insufficient

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[29] *Gold Standard Validation Report for the National Biodigester Programme, Cambodia*, by the Swiss Association for Quality and Management System (SQS), auditors: Mr Rudolf Brodbeck & Mr Michael Gassner, July 2011.

[30] http://www.livelearn.org/projects/floating-bio-digesters-waste-management-and-energy-recovery-floating-bio-digester-project

demand for the electricity generated. The villagers did not purchase new electricity-using equipment as originally anticipated leading to the search for alternative users of the electricity (e.g. in powering irrigation systems). Key to making such plans viable would be limiting the transaction costs and ensuring that there is a reasonable match between supply and demand such that the gasifier can be kept operating for sufficient periods of time for it to be economic. Note that there is now a functioning village –scale Ankur gasifier providing electricity to a local micro-grid. The project has been supported by UNIDO and is located close to Siem Reap town.

The price of rice husk and thus of paddy may increase with an increased use of this resource: farmers might begin to demand a higher price for rice paddy, seeing that it contains not just the valuable edible rice but also the husks, which now have a value of between $31 and $39 in Thailand[31] and prices in parts of India seem to be similar.[32]

Finally, a suitable disposal for the biochar produced through the gasification process has to be found (c. 30% of the rice husks by mass are transformed into chars[33]). This biochar can be sold to farmer and used as fertilizer, or as charcoal in brick kilns.

Waste Water Management**:** The three major legislative tools related to the management of waste waters are the following. A more detailed analysis of the legislative requirements is provided in section 3.2, 'Analysis of laws and technical standards'):

- Sub-decree on Water Pollution Control (enacted by the Council of Ministers in 1999, under the Article 13 of the Law on Environmental Protection and Natural Resource Management);
- Drinking Water Quality Standards (CDWQS) (issued in Jan 2004 by the Ministry of Industry, Mines and Energy). These standards are only relevant if the waste water discharge is likely to intrude into public drinking water supplies;
- Law on Water Resources Management of the Kingdom of Cambodia (June 2007).

The Sub-Decree, law and quality standards state that the waste water has to be treated before being released into the environment, an authorization being required to do so in all cases. Maximum permissible limits (MPLs) have also been established for some organic and inorganic chemical concentrations in the released waste water.

Licensed owners / managers of factories or other pollution sources should ensure that their waste water effluents are properly treated. The owner or manager must ask for permission to discharge treated waste water into public water courses. Category 65 to which the Sub-Decree applies is Power plant while category 11 is *Feed mill manufacturing*, so it seems that the gasifiers do fall under the provisions of the Sub-Decree.

The CDWQS are only relevant if the waste water discharge is likely to intrude into public drinking water supplies. In all the cases that we observed, there is no evidence of drinking water extraction from any of the ponds which receive the waste water. However, if waste water slowly enters the water table, which is close to the surface in many delta areas, it is possible that contaminants may

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[31] Parnphuneesup, P., Kerr, S., 2011. Stakeholder preferences towards the sustainable development of CDM projects: lessons from biomass (rice huks) CDM projects in Thailand. Energy Policy 39, 3591–3602.
[32] Simon Shackley pers.com., India workshop, Nov. 2010;
[33] Shackley, S., et al., Sustainable gasification–biochar systems? A case-study of rice-husk gasification in Cambodia, Part I: Context, chemical properties, environmental and health and safety issues; Energy Policy (2012), 42: 49-58.

flow laterally and intrude into a source of drinking water. The CDWQS provide guidance on the testing frequency and sampling protocol.

Because of poor law enforcement in Cambodia, rice mills are most of the time not equipped with waste water treatment systems and black waters are just released into a pond and may overflow into the closest stream or seep into the ground, hence getting into the ground water. These practices may cause: 1. drinking water contamination with heavy metals and/or organic contaminants, particulate matter, oils and grease; 2. ecological damage in water ways (e.g. increase biological and chemical oxygen demand; toxic chemicals); 3. soils contamination (with attendant risks for food production and future uses of that land).

The **Law on Environmental Protection and Natural Resource Management** (NS/RKM/1296/36 dated 24/12/1996) also has to be respected for any project likely to have an impact on the environment. Consisting of 27 articles, this law aims to protect and upgrade environmental quality, to assess impacts on the environment (Environmental Impact Assessment procedure, sub decree on EIA (Aug 1999), to ensure rational and sustainable preservation of the environment, to avoid and eliminate any activities adversely affecting the environment, etc. But the lack of detailed sub-decrees, the lack of enforcement mechanisms and processes have led to the reality that very few EIA have been undertaken in the past 5 years (only 5% of all the projects, according to the MoE).

In summary, while there are, on paper, legislative requirements on EIA and environmental management, in reality the lack of law enforcement in Cambodia means that such legislative barriers to gasification projects are hardly evident.

The emergence of local copycat manufacturers permits a decrease in the price for the installation of a gasifier. But the initial cost may still remain too high for the miller, who could have difficulty paying for this technology without financial incentive, still lacking in Cambodia. However some efforts are on the way (Feed-in-Tariff possibility for the future, MFIs loans, etc.). The lack of skills and knowledge brings a limit to the expansion of gasification technology in Cambodia.

3.2. Analysis of Laws and Technical Standards

This section presents a review of laws and technical standards for waste management in Cambodia. Some of them have already been tackled in the Barrier Analysis (¶ 3.1).

The main reference for all environmental legislation in Cambodia is the ***Law on Environmental Protection and Natural Resource Management*** (NS/RKM/1296/36 dated 24/12/1996). According to Art.1, the purpose of the law is to protect and upgrade environmental quality and public health by means of prevention, reduction and control of pollution, to assess the environmental impact of all proposed projects, to ensure sustainable development and management of the natural resources, to suppress any acts which may cause harm to the environment as well as to encourage and provide possibility for the public to participate in the protection of the environment and the management of natural resources.[34] § 3 in the **Law on Environmental Protection and Natural Resource Management** is dedicated to the Environmental Impact Assessment and requires a thorough assessment of impacts on the environment due to the installation of rice-husk gasification systems.

[34] Law on Environmental Protection and Natural Resource Management (1996) [Online] Available at http://www.opendevelopmentcambodia.net/law/en/LAW-1296-36-96-Environmental-Protection-Natural-Resources-Mgt-E.pdf

According to article 6, an EIA shall be carried out on ''every project and activity of either private or public and shall be examined and evaluated by the Ministry of Environment before it is submitted to the Royal Government for decision. This assessment shall also be applicable for those existing activities and those which are under development and for which environmental impacts need to be assessed.''[35]

A Sub-decree of the Law requires the developer to devise concrete procedures to carry out EIA. The Sub decree on Environmental Impact Assessment Process (No: 72 ANRK.BK Phnom Penh) was issued by the Cambodian government in 1999 and applies to ''every proposed and on-going project(s) and activities, either by private, joint-venture or state government, ministry institutions of which are described in the Annex.'' Category IX of the Annex to the Sub-decree includes Waste Processing activities of all sizes in the list of project which are required to carry out a full EIA.[36] However, official records report that between 2004 and 2011 only 5% of the required projects have carried out an EIA. This is due to the lack of details of implementation procedures in the sub-decree and a lack of enforcement.

Currently the Ministry of Environment in cooperation with the Vishnu Law Group of Cambodia and international EIA experts Matthew Baird and Richard Frankel is drafting a ***Law on Environmental Impact Assessment*** with the purpose of setting out provisions, principles, standards, procedures and measures on EIA in Cambodia. The first draft of the Law was issued in 2011. Since then several updated versions of the Law have been produced by Vishnu Law Group and key stakeholder both from the private and public sector have been consulted. On 22-23 November 2012, Nexus participated in *The Consultation Workshop on the Draft Law on Environmental Impact Assessment* organized by the MOE. Nexus asked EIA expert Matthew Baird when the *Law on Environmental Impact Assessment* is due to enter into force. Mr Baird's hope is that the Law will be sent to the Council before June 2013 and enter into force in late 2013/2014.

This law will certainly have an impact on the Rice Milling Sector in Cambodia. An EIA is likely to be required both for the construction of new mills and for any new power-generation and / or waste management facility such as the rice-husk gasifiers. However, at this stage there is no clear indication on when the Law will come into effect. Nexus will closely follow future development and submit feedback to SNV and key stakeholders accordingly. [37]

Another piece of legislation which is likely to have an impact on the development of a rice-husk gasification project in Cambodia is the ***Law on Water Resources Management of the Kingdom of Cambodia*** (20/07/2007)[38]. The general purpose of this Law is to ''foster the effective and sustainable management of the water resources of the Kingdom of Cambodia to attain socio-economic development and the welfare of the people. This Law determines: the rights and obligations of water users, the fundamental principles of water resources management, and the participation of users and their associations in the sustainable development of water resources.'' According to article

[35] Law on Environmental Protection and Natural Resource Management (1996) [Online] Available at http://www.opendevelopmentcambodia.net/law/en/LAW-1296-36-96-Environmental-Protection-Natural-Resources-Mgt-E.pdf

[36] Sub decree on Environmental Impact Assessment Process (No: 72 ANRK.BK Phnom Penh) (1999) [Online] Available at http://www.sithi.org/admin/upload/law/72%20on%20the%20Environmental%20Impact%20Assessment%20Process%20%281999%29.ENG.pdf

[37] To read the text of the draft law, send an e-mail to Eleonora Gatti at e.gatti@nexus-c4d.org.

[38] Law on Water Resources Management of the Kingdom of Cambodia (2007) [Online] Available at http://www.google.com.kh/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CDoQFjAA&url=http%3A%2F%2Ffaolex.fao.org%2Fdocs%2Ftexts%2Fcam75723.doc&ei=cnPBUIq_CczMrQf374DoAg&usg=AFQjCNEP83-kqjiST_xje76UANdlLwqLNA

22 ''a license or authorization is needed for the discharge of any substance likely to deteriorate the quality of water (...) sanctions apply if the installation has no authorization.'' This article needs to be taken into account when managing waste water that has been used to clean tars from the syngas produced by rice husk gasification.

With regards to technical standards only the national standard on Drinking Water and Water Contamination have been found. The desk-based review did not identify any outcomes concerning standards on soil and air pollution.

The **Sub-Decree on Water Pollution Control** (SDWPC) enacted in 1999 by the Council of Ministers aims to control waste water discharges in order to maintain water quality. It is enacted under article 13 of the Law on Environmental Protection and Natural Resources Management. The Sub-Decree focuses upon public water areas. Licensed owners / managers of factories or other pollution sources should ensure that their waste water effluents are properly treated. The owner or manager must ask for permission to discharge treated waste water into public water courses. Category 65 to which the Sub-Decree applies is Power Plant while category 11 is Feed Mill Manufacturing, so it seems likely that the gasifiers do fall under the provisions of the Sub-Decree.

The Sub-Decrees distinguishes between waste water discharge to protected public water areas (a higher standard) and to public water areas and sewers (a lower standard). These standards can be used in an evaluation of the waste water stream from the gasifiers. The Sub-Decree also provides Water Quality Standards for receiving waters – rivers, lakes and reservoirs. These standards can be used in an evaluation of the water course into which waste water from the gasifiers has been discharged. There are separate Water Quality Standards for public health protection and these are also useful in evaluating the health impact of waste water discharge if human exposure is likely.

The other major regulation controlling water quality in Cambodia is the **Drinking Water Quality Standards (CDWQS)**, issued in January 2004 by the Ministry of Industry, Mines and Energy. The Law complies with 2003 Drinking Water Quality Guidelines from World Health Organization. "The aims of these standards are to ensure that drinking water will be safe in the future, that there are no health risks to the public, (…). They should be used along with sanitary surveys and barriers to prevent contamination of water supplies.'' The maximum permissible limits (MPLs) are set by the CDWQS alongside guidance on the testing frequency and sampling protocol. CDWQS standards concern the rice mills gasifiers only when waste waters are released in a point connected to a drinkable water source. While it is very unlikely that any of the water bodies into which waste waters are being discharged are used directly for drinking water, the high level of the water table in the low-lying delta areas where many gasifiers are located (e.g. Battambang, Siem Reap, Kandal provinces), in particular during the rainy season, means that waste water may well disperse laterally as well as vertically, thereby contaminating water bodies that are used for extracting drinking water supplies. Further hydrological research would be necessary in order to evaluate how large this risk might be.

Results from the **Barrier Analysis** to renewable energy production and consumption show that there are no major legislative barriers in Cambodia. Legislative barriers may occur as a result of the environmental impact of disposal of by-products from the gasification process. A Law on Environmental Impact Assessment, setting out provisions, standards and procedures to carry out EIA in Cambodia, is currently being developed. Technical standards on water pollution control - Sub-Decree on Water Pollution Control and quality of drinking water - Drinking Water Quality Standards in particular need to be taken into account during the development of a carbon project in the rice-husk sector. Results from the Barrier Analysis highlight that technical and socio-economic barriers can be identified. Technical barriers are due to the limited skills and knowledge to comply with standards and technical specification of technologies in use. Technical assistance from the international expert is indeed needed. Economic barriers stems from the fact that very often energy efficient technologies are more expensive than the traditional ones and require an higher upfront investment. Social barriers stems from the introduction of a new type of technology, especially if imported from other countries and dissimilar to local technology, in the Cambodian rice milling sector.

4. Results: Baseline Study

Chapter 4 presents a summary of Baseline Study results carried out in cooperation with Domrei.

4.1. Summary of the Results: Mills without RHG

A total of 30 mills without gasifiers were interviewed in December 2012 across the nine targeted provinces.

4.1.1. Milling activity: seasonality

Table 7: Milling activity: high season

	High Season (from)		High Season (to)	
Month	Freq.	Percent	Freq.	Percent
January	9	30.0	0	0
February	4	13.3	2	6.7
March	2	6.7	3	10.0
April	3	10.0	1	3.3
May	1	3.3	5	16.7
June	0	0	0	0
July	0	0	3	10.0
August	0	0	4	13.3
September	1	3.3	3	10.0
October	1	3.3	6	20.0
November	2	6.7	0	0
December	7	23.3	3	10.0
Total	30	100	30	100

Table 8: Milling activity: low season

	Low season (from)		Low season (to)	
Month	Freq.	Percent	Freq.	Percent
January	2	6.7	3	10.0
February	0	0	4	13.3
March	2	6.7	3	10.0
April	4	13.3	0	0
May	2	6.7	0	0
June	2	6.7	0	0
July	1	3.3	0	0
August	2	6.7	1	3.3
September	4	13.3	2	6.7
October	4	13.3	3	10.0
November	6	20.0	4	13.3
December	1	3.3	10	33.3
Total	30	100	30	100

Based on the tables above, during the Feasibility Assessment the high season was considered to be from January till October and the low season from November till December.

4.1.2. Milling activity: production

The milling capacity is the maximum amount of paddy the mill can process per hour. For the baseline survey sample, only mills that have a capacity of at least one ton per hour have been considered[39]. The average sample capacity is 2.16 tons/h (with a minimum of 1 ton/h and a maximum of 5 tons/h).

Table 9: Mill production[40]

Production	Paddy		Milled rice		Bran		Rice husk		Broken kernels	
	High season	Low season	High season	Low season	High season	Low season	High season	Low season	High season	Low season
Average tons per day	22.18	10.37	14.08	6.49	2.67	1.26	3.24	1.41	1.56	0.57
Standard Deviation	13.42	7.83	8.76	5.25	1.71	1.17	2.76	1.21	1.67	0.45
Minimum tons per day	5.0	0.0	3.0	0.0	0.2	0.0	1.0	0.1	0.2	0.0
Median tons per day	20.0	8.5	12.0	5.0	2.1	1.0	2.7	0.9	1.0	0.6
Maximum tons per day	60.0	30.0	40.0	20.0	7.0	5.0	12.0	3.8	8.0	2.0
Sum	665.3	311.0	422.4	194.6	80.1	37.8	58.4	25.4	43.7	16.1
N	30	30	30	30	30	30	18*	18*	28*	28*

*does not include those who answered “don't know”

Table 10: Prices for paddy, milled rice, bran and broken kernels (in riel)[41]

Price	Paddy		Milled rice		Bran		Broken kernels	
	High season	Low season	High season	Low season	High season	Low season	High season	Low season
Average price per kg	990	1,210	1,612	1,851	677	977	1,134	1,327
Standard deviation	169	225	357	423	224	165	294	333
Minimum price per kg	700	650	980	1,100	300	650	140	160
Median price per kg	950	1,200	1,510	1,800	600	1,000	1,200	1,400
Maximum price per kg	1,400	1,800	2,600	3,000	1,500	1,200	1,500	2,000
Sum	29,685	36,310	48,363	55,525	20,310	29,310	34,030	39,810
n	30	30	30	30	30	30	30	30

[39] as requested by SNV during Inception Meeting;

[40] For the high season, the total is 21.55 tons, not far from the mean value of 22.18 tons of paddy processed (630kg difference; 97.2% accuracy). In the low season, the total of the mean values of all the products is 9.73 tons, compared to 10.37 tons of paddy milled (a difference of 640kg; 93.8% accuracy). These differences could be due to the respondents' mistakes, or to the fact that it is difficult to assess the exact quantities for each component, especially when we know that some of them can easily fly away, such as the bran and rice husks.

[41] 4,000 Cambodian riel = approximately 1 US dollar (USD)

The millers were then asked how many tons of milled rice they sell per year, in order to compare with the milled rice they produce (to see if the millers sell everything they produce). On average, the respondents sell 1,636 tons of milled rice per year, with a minimum of 200 tons (probably for the mills with the smallest capacities) and a maximum of 9,000 tons.

The average yearly maintenance expenditure for the mills reaches USD 12,956 (mean value calculated among 25 mills only; the other five were unable to answer the question). This amount includes the maintenance of the whole milling installation (from the milling machines to the lighting system in the building). Some millers do not spend anything in a year for this component (minimum of USD 0.00) whereas large costs occurred in other mills (maximum of USD 60,000).

4.1.3. Mill characteristics

Table 11: Percentage of female employees

Answer	Freq.	Percent
No	18	60
Yes	12	40
Total	30	100

Table 12: Working conditions

Criterion	Male		Female	
	High season	Low season	High season	Low season
Average number of staff	9.2	5.8	2.8	2.2
Average working hrs/day	8.4	5.6	7.5	5.8
Average working days/wk	6.8	5.8*	6.8	6.3
Average salary rate/day	25,503	17,463	11,925	10,258
n	30	30	12	12

*n=29 for this mean value: one mill did not answer.

As shown in the table above, only 40% of the mills employ women. The male/female employee ratio is largely unbalanced in mills with female staff, with the number of female staff far below the average number of male employees, although the numbers of female staff remain more constant throughout the year. In addition, women work approximately as many hours and days as men, but get paid approximately two times less.

Table 13: Information provided to employees about milling process

Answer	Freq.	Percent
No	1	3.3
Yes	29	96.7
Total	30	100

Table 14: Completeness of information provided to employees about milling process

Information	Freq.	Percent
Basic	15	51.7
Complete	14	48.3
Total	29	100

If almost all the millers provide some amount of information or training to employees when they start working in the mill, only 48% of them provide a complete explanation about how all of the machines work, the detailed production processes, etc. Around 52% of millers only provide basic instructions to the workers about their tasks and responsibilities, without the mechanical, technical and processing details.

4.1.4. Rice husk disposal and the gasification alternative

The millers were asked about their rice husk storage duration. Although the mean value is 81 days, the results vary from 0 to 365 days (minimum and maximum respectively; median value = 25 days).

Figure below shows that 63.3% (n=19) of the millers sell their rice husks, whereas around 10% store it at the mill. About 33.3% of the millers find other ways to dispose of rice husks; generally, they give it for free to farmers.

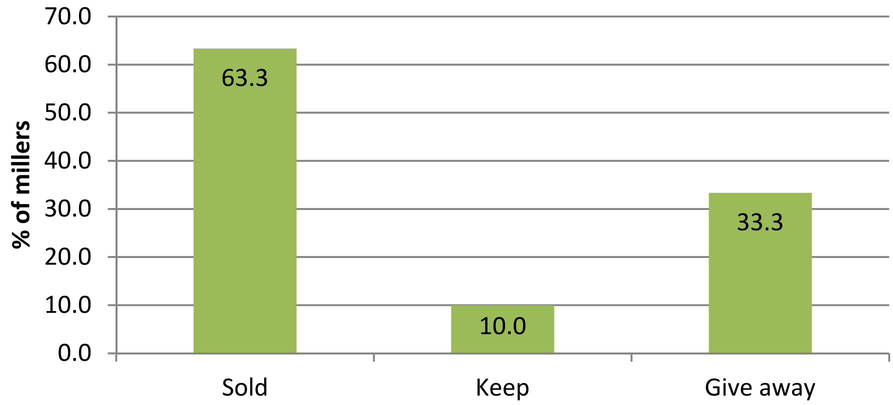

Figure 3: Rice husk disposal

The millers who do not keep rice husks sell 70% of their stock. The different customers are detailed in Figure 4. The millers find other ways to dispose of the remaining 30%.

Once the rice husks are sold, it is interesting to know how the customers use them. Figure 5 shows that in about 64% of the cases, rice husks are burnt as fuel (in stoves to produce alcohol or palm sugar, in gasifiers for electricity, etc.). 25.6% of the sold rice husks are used as food for animals, mainly for pigs. Only 10.2% are used for fertilizer (burned and then used as fertilizer, or not burned and directly incorporated into non-irrigated rice fields). No use of risk husks for compost, raw material or incorporation into irrigated rice fields has been reported.

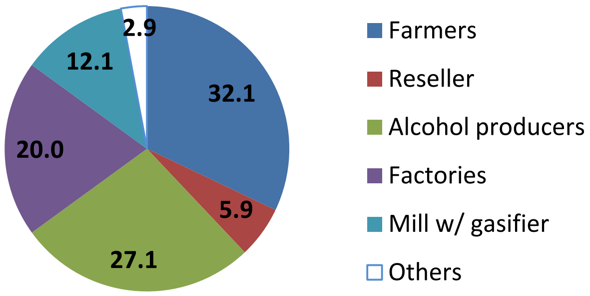

Figure 4: Rice husk customers

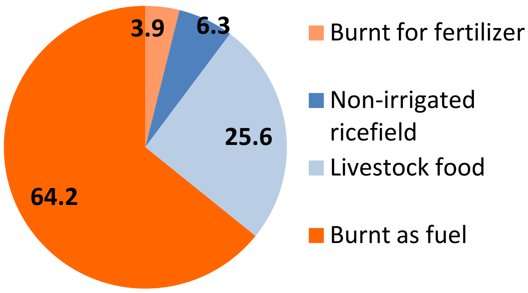

Figure 5: Rice husk usage

Figure below shows what the millers consider the main problems for rice husk storage.

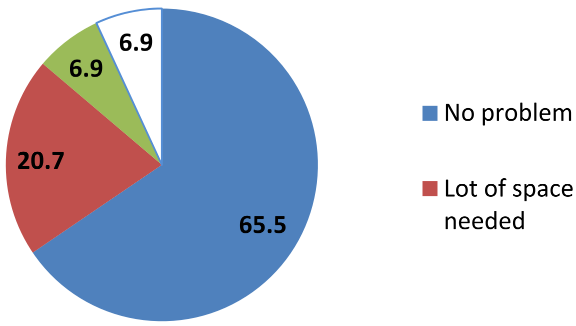

Figure 6: Main problems linked with rice husk storage

Most of the time, the respondents do not have any inconvenience with the rice husk storage, but for 20.7% of them, the space needed is the main problem. Actually, 26.7% of the millers built a shed especially for rice husk storage, which cost on average USD 2,231 (minimum USD 300 and maximum USD 5,000). Another problem for 6.9% of the respondents is the fire risk: rice husks are rather dry, and burn easily.

All the millers have already heard about rice husk gasification technology, from diverse sources as detailed in Figure 7. Gasifier promoters and mill colleagues are the first sources of this information; around 73% of the millers heard about the gasification alternative from them.

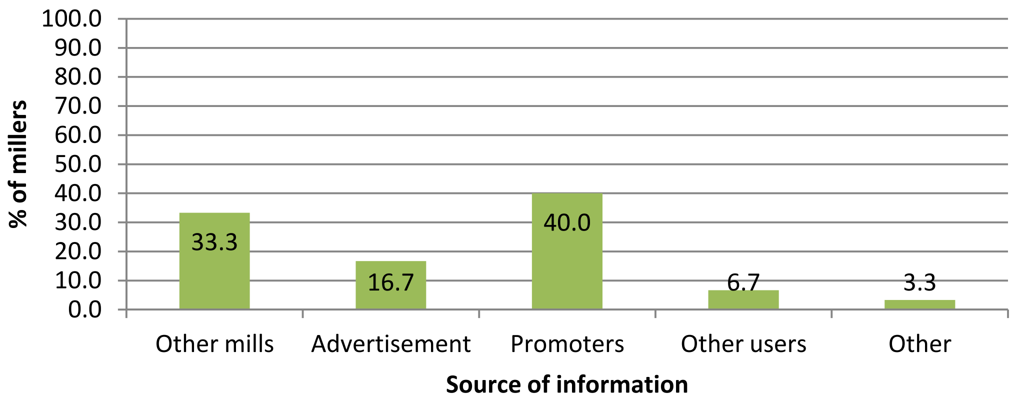

Figure 7: Source of information about RHG

41.4% of the millers in Figure 8 explain that they do not have a gasifier because it is too expensive, and 31% because it takes too much space. An additional 13.8% worry about the environmental impact of such an installation. Surprisingly, some millers think that the gasifier is not reliable because it is too weak (easily breaks down; 10.3%), and would decrease their milled rice production (10.3%).

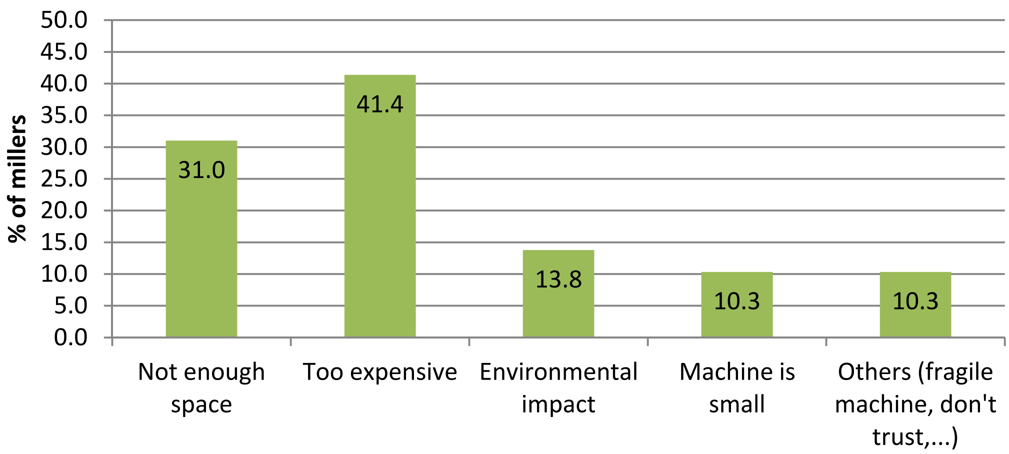

Figure 8: Reasons why millers are not equipped with RHG

4.1.5. Energy consumption

Two kinds of energy at the mills were examined: the energy provided through the local electricity grid; and the energy produced off-grid, by a generator into the mill.

Only 26.7% (n=8/30) of the interviewed millers said that their mill is connected to the local electricity grid. In 87.5% of the cases, this electricity comes from a public supplier. The price the millers actually paid when we interviewed them ranged from 820 to 1,200 riel/kWh (mean value 1,153 riel/kWh).

One of these eight millers observed a price variation throughout the year (from 1,100 riel/kWh to 1,250 riel/kWh).

The average monthly costs for grid electricity are 2,981,250 riel (USD 745). However, there is wide variation in responses to this question with several very high costs. Therefore the median cost may be a better measure of normal operating costs for the mills. The median monthly costs for grid electricity were 550,000 (USD 137). The maximum monthly grid electricity cost for one mill was 19,000,000 riel (or USD 4,750), probably because it uses electricity from the grid exclusively and does not produce its own energy with a generator.

The 22 millers without grid electricity were then asked why they are not connected to the local power grid (Figure 9). The first reason is financial, with 45.5% of the millers complaining about the price of electricity. 18.2% think the local grid is too far from their mill, while 13.6% do not trust the electricity grid's reliability (too many shortages and power cuts). 13.6% affirm that their mill is not modern enough to use the grid electricity.

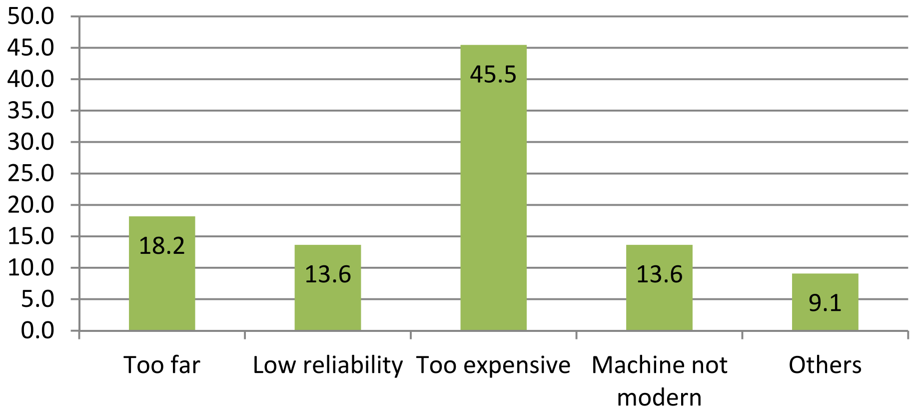

Figure 9: Reasons why millers are not connected to the electricity grid

The 22 unconnected millers were asked whether they plan to get a connection to the grid in the future; 81.8% answered "yes". Their reasons are given in the figure below. Almost 39% of the millers think that this source of energy will be cheaper than the one they use currently, whereas about 28% believe in new modern milling machines (which, they suppose, are able to use grid electricity). 16.7% simply do not want to use diesel fuel anymore. The millers who do not plan to switch to the electricity grid (n=4) said that the grid electricity is still too expensive (75%) and not reliable (25%).

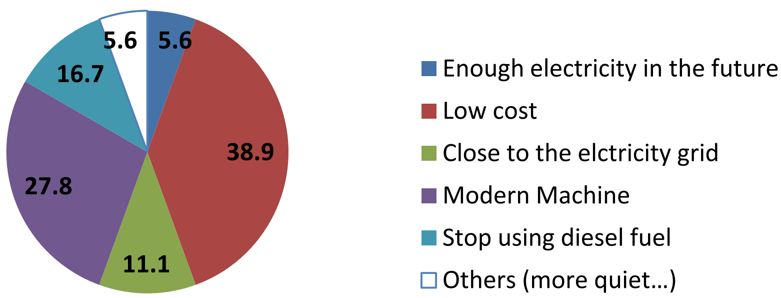

Figure 10: Main reasons for the millers to get connected to the electricity grid (%)

90% (n=27/30) of the millers produce their own energy, which implies that some mills use both the local grid electricity and their own generator. The three mills that do not produce their own energy consider that electricity from the grid is sufficient for their operations.

4.1.6. On-site generators

Table 15: Number of working generators among the 30 mills

Number of generators	Freq.	Percent
One	**25**	**88.9**
Two	2	7.4
Three	1	3.7
Total	**28***	**100**

**2 mills did not give any data*

Most of the mills are equipped with a single generator, and for 28 mills, there are a total of 32 generators. Thirty of these generators (93.8%) are used for the milling process. Two generators are used for other purposes (bag sewing, light, aeration, etc.). 68.8% of the 32 generators are also used to run the machines that sew the rice bags; for the remaining 31.2%, this activity is ensured by another source of energy: another generator if the mill is equipped with several of them, or another kind of energy (electricity from the grid, or even manual sewing).

Capacity characteristics of 31 generators,[42] in both hph (horsepower hours) and kWh (kilowatt hours), is presented in the able below. The three low-capacity generators (8, 10 and 16 hph) are probably used for low energy consumption purposes (lighting, aeration, etc.).

Table 16: Capacity of the generators

Capacity of generator (hph)	Capacity of generator (kWh)	Freq.
8	5.97	1
10	7.46	1
16	11.93	1
120	89.48	2
160	119.31	1
230	171.51	3
300	223.71	3
305	227.44	1
320	238.62	3
340	253.54	1
350	260.99	3

[42] One miller declined to provide this information.

360	268.45	2
380	283.37	1
390	290.82	1
400	298.28	5
450	335.56	1
500	372.85	1

The table below shows that the average capacity value for these 31 generators is 294.16hph, or 219.36kWh. If we do not take the three low-capacity generators into account, these mean values become 324.46hph and 241.95kWh.

Table 17: Capacity of the generators (statistics)

	mean	sd	min	p50	max	sum	n
hph	294.16	128.14	8	320	500	9119	31
kWh	219.36	95.55	6	239	373	6800	31

The different generator brands are presented in the figure below. Mitsubishi and Hino, Japanese brands, are the most represented among the millers, covering 78.2% of all generators recorded.

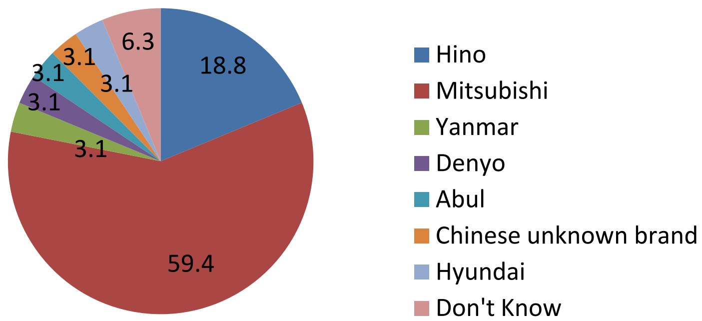

Figure 11: Main reasons for the millers to get connected to the electricity grid (%)

81.3% of the generators provide mechanical energy to the milling machines, 12.5% produce electrical energy, and 6.3% produce both.


Figure 12: Mitsubishi diesel generator (400hp), delivering electrical energy

The table below compares the daily and weekly working durations for the generators between the low and high activity seasons, as well as the daily diesel consumption. In a month (4 weeks) a generator would thus use 4,971.4L in the high season and 1,664.04L in the low season.

Table 18: Generator working characteristics[43]

Components	Mean value	
	High season	Low season
Running hours/day for the generator	8.3	4.2
Running days/week for the generator	6.7	4.9
Daily diesel consumption for the generator (L)	185.5	84.9

4.1.7. Data collection, record keeping and data management

The millers were asked how they collect data for their business, including information on employment, production, energy consumption and finances.

Figure below shows the data collection habits of the respondents. For most of the milling activity components, the millers simply do not record any data. Only finances incite most of the millers to collect information, and they primarily record this information on paper (66.7%). The area of least concern to millers is their energy consumption; 83.3% do not collect any data about this aspect of their business. Thus, they might not know how much they could save by using a different kind of energy (rice husk gasification, for example).

Only 26.7% of the mills are equipped with an electricity meter, and half of them never monitor it (the other half usually makes readings once a month).

[43] The low-capacity generators were taken into account (8, 10 and 16 hph).

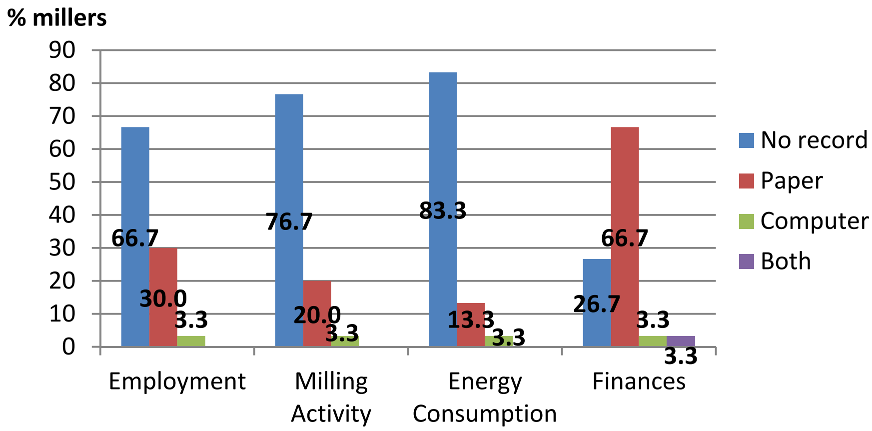

Figure 13: Mill data collection

Among the mills which collect data, 48% never analyze them. 28% manage the data in basic ways: use/compare receipts (probably for costs/benefits only), or simply keep the data on paper. 24% of the mills use statistical analysis to examine their data.

Among the millers who collect data, 24% agree that they would share and exchange the information publicly, including sharing it with the government (50%), other millers (33.3%), and the Cambodian National Rice Millers Association (16.7%).

4.2. Summary of the Results: Mills with RHG

Five mills equipped with the gasification technology were visited for this survey. Domrei field staff used the same instrument for the mills without gasifiers, and added two sections about the gasifier and its potential environmental impact. This section of the report provides details on the two sections of the questionnaire that differs from the questionnaire for mills without RHG.

4.2.1. Milling activity: production

For these five mills, the mean milling capacity is 5.5 tons/h.

Table 19: Mill production

Production	Paddy rice		Milled rice		Bran		Rice husk		Broken kernels	
	High season	Low season	High season	Low season	High season	Low season	High season	Low season	High season	Low season
Average tons per day	46.40	28.80	24.63	14.15	4.72	2.42	9.83	7.85	5.07	2.35
Standard deviation	29.58	38.23	9.62	14.61	2.74	3.48	12.79	13.97	3.48	3.30
Minimum tons per day	20.0	6.0	15.0	4.5	1.5	0.5	1.5	0.6	0.5	0.2
Median tons per day	38.0	10.0	20.0	6.5	4.5	1.0	4.5	1.0	5.0	0.5
Maximum tons per day	96.0	96.0	39.4	39.4	8.6	8.6	28.8	28.8	9.0	7.9

Sum	232.0	144.0	123.2	70.8	23.6	12.1	39.3	31.4	25.4	11.8
n	5	5	5	5	5	5	4*	4*	5	5

** one miller did not provide data*

The table above gives the mean production values of the mills with gasifiers. If we use the same calculations from Table 9 to compare the sum of the products (milled rice, bran, rice husk, and broken kernels) to the paddy processed, we obtain a total production of 44.25 tons of products in the high season, 2.15 tons lower than the 46.4 tons of paddy taken in (95.4% accuracy), and 26.77 tons in the low season, 2.03 tons lower than the 28.8 tons of paddy (93% accuracy).

In addition, we can calculate the portion of each product and by-product compared to the total production of the mill. In the high season, milled rice represents 55.7% of the production, bran represents 10.7%, rice husk represents 22.2%, and broken kernels represent 11.4%. In the low season, milled rice is 52.9%, bran is 9.0%, rice husk is 29.3%, and broken kernels are 8.8%. The milling recovery for these five mills is thus not very good, with only a little more than half the paddy quantity being transformed into milled rice.

4.2.2. Mill characteristics

Table 20: Chronology for mills with gasifiers

Opening year	Gasifier installation	Manufacturer	Start data collection
1987	2007	Lim Hieng	2007
1989	2008	Chanrith	1989
1995	2012	Chanrith	1995
2007	2007	Chanrith	2007
2009	2009	Ankur	2011

Only two mills out of five employ women. Like the mills without gasifiers, The table below shows that for approximately the same number of working hours (except in the high season, when men seem to work longer), women are paid much less than men. In the high season, men earn around 9,360 riel per hour (USD 2.30) whereas women only get around 1,920 riel per hour (USD 0.50).

Table 21: Working conditions

	Male		Female	
	High season	Low season	High season	Low season
Average number of staff	17.00	11.60	11.00	11.00
Average work hrs/day	8.40	5.60	6.00	6.00
Average work days/wk	6.80	6.40	6.50	6.50
Average salary rate/day	78,600	73,200	11,500	11,500
n	5	5	2	2

All the millers provide staff training on the milling activities, but four of the millers provide only basic information about their activities and procedures. As a consequence, most of the staff just know about their assigned tasks, and have very limited knowledge about the other milling processes.

4.2.3. Rice husks disposals and the gasification alternative

The amount of time that millers store their rice husks is shown in the table below.

Table 22: Rice husk storage duration

Storage duration	Freq.	% distribution
Less than 1 day	1	20.0
1 day	2	40.0
2 days	1	20.0
30 days	1	20.0
Total	**5**	**100.0**

Millers were then asked how they dispose of their rice husks.

Table 23: Rice husk disposal methods

Disposal method	% distribution
Used as fuel	42.0
Sold	44.0
Kept	14.0
Total	**100.0**

More than 80% of the rice husk stock is either burnt in the gasifier or sold. When rice husks are sold, the customers burn them for use as either fuel or fertilizer. The primary customers of these rice husks are factories (43.7%), which use them as fuel in stoves and kilns (to build masonry bricks, for example), and gasifiers (32.7%) which are not associated with a mill and consequently needs to buy rice husks to produce electricity. An additional 13.7% of the rice husks are used as fuel by alcohol producers.

Figure 14: Rice husk stockpiles

Table 24 and Table 25: Rice husk customers and usage of sold rice husk

Customers	% distribution
Farmers	10.0
Alcohol producers	13.7
Factories	43.7
Others (Gasifiers which produce electricity, no association with a mill)	32.7
Total	**100.1**

Rice husk use	% distribution
Burnt as fertilizer	10.0
Burnt as fuel	90.0
Total	**100.0**

These five mills sell rice husks at an average price of 24,867 riel/ton (24.87 riel/kg), equivalent to USD 6.20 per ton (USD 0.0062 per kg). The price is the same in both high and low activity seasons. This price is much lower than the one we obtained from the mills without gasifiers.

Three of the five millers do not have any problem with rice husk storage. One miller said that the main problem was preventing their decomposition, and one miller did not answer this question. Two millers actually built hangars to store the rice husks, at costs of USD 5,000 and USD 10,000 respectively. Other than this, no further development has been undertaken for rice husk storage by these millers.

4.2.4. Energy consumption

Only one of the five mills is connected to the local electricity grid, but it also uses a generator to produce its own energy. This mill pays 1,200 riel/kWh for grid electricity, and has an average monthly expenditure of 5,000,000 riel (USD 1,250) for this electricity.

The four other mills think that grid electricity is currently too expensive, but plan to get connected in the future. There are several reasons for this: some are confident that the price will decrease (n=2), another mill is close to the grid (n=1), and another miller believes he will spend less money for diesel (n=1) by supplementing his power supply with grid electricity.

There are a total of six generators in these five mills: four mills are equipped with a single generator, and one mill has two generators. The six generators are used for the rice milling process and for sewing the rice bags. The table below shows the generator capacities.

Table 26: Capacity of the generators

Capacity of generator (hph)	Capacity of generator (kWh)	Freq.
350.0	261.0	1
380.0	283.4	1
450.0	335.6	1
800.0	596.6	1
1000.0	745.7	2

Table 27: Capacity of the generators (statistics)

	mean	sd	min	p50	max	sum	n
hph	663.3	306.4	350.0	625.0	1000.0	3980.0	6
kWh	494.6	228.5	261.0	466.1	745.7	2967.9	6

The table below shows the different brands of generators owned by the five mills. All of the generators deliver mechanical energy to the mill, and use both gasoline and diesel fuel.

Table 28: Generators brands

Brand	Freq.	Percent
Hino	2	33.3
Komisu	2	33.3
Mitsubishi	1	16.7
Komin	1	16.7
Total	**6**	**100**

Table 29: Generator working characteristics

	Mean value	
	High season	Low season
Running hours/day for the generator	8.3	5.3
Running days/week for the generator	6.7	4.3
Daily diesel consumption for the generator (L)	355.0	318.3

These mills spend on average 4,233 riel per litre of diesel (minimum 3,800 riel and maximum 4,800 riel; n=4). Thus, in one month (four weeks) of high season activity, they spend on average 6,010,150 riel (USD 1,500) for diesel, and 5,388,819 riel (USD 1,347) per month in the low season. This daily diesel consumption corresponds to the quantity of fuel needed by the generators, and does not take into account any fuel consumption by the gasifiers.

4.2.5. Gasifier characteristics

All the gasifiers were installed very recently (maximum five years ago), and only two of them were installed at the same time as the mill was built. Millers heard about this technology mainly from other millers (40%) and promoters (40%), and all five mills decided to invest in a gasifier system because of the increasing cost of diesel.

Figure 15: Gasifier reactor[42]

Rice husks are burnt inside the reactor at temperatures up to 1000°C.

Only one mill had a small generator before it purchased the gasifier. When it installed the gasifier, it also increased its generator capacity from 500hph to 800hph (372.8kWh to 596.6kWh). For this mill, the gasifier was an additional source of energy, whereas for the four other mills (which kept the same generator capacity) the gasifier partially replaced the energy produced by the diesel generator.

Four millers provided some training or information to their employees about the gasifier system. Three millers gave complete information, explaining all the processes within the gasifier system, and one just gave basic instructions (fill the hopper, check parameters like temperature, manage the wet char discharge, etc.). One miller did not provide any training to its staff.

Four of the five gasifiers were manufactured by local Khmer companies. Three of the gasifiers were manufactured by Nou Chan Reth (aka Nou Chanrith), and one was made by Lim Hieng, both local Khmer companies. One gasifier was manufactured and imported from India by Ankur.

Table 30: Gasifier characteristics, compared with associated generators

Mill gasifier	Komisu (n=2)	Komin	Hino	Hino	Mitsubishi
Associated generator (hph)	1000	800	450	380	350
Manufacturer	Ankur	Lim Hieng	Nou Chan Reth	Nou Chan Reth	Nou Chan Reth
Supplier	Nou Chan Reth	Lem Thon	Nou Chan Reth	Nou Chan Reth	Chun Kem Heng
Installation firm	Nou Chan Reth	Lem Thon	Nou Chan Reth	Nou Chan Reth	Nou Chan Reth

Maintenance firm	Nou Chan Reth	Lem Thon	Nou Chan Reth	Nou Chan Reth	Heng SeangHeun
Gasifier capacity (hph)	800	500	400	200	350
Initial investment (USD)	154,000	45,000	45,000	30,000	40,000
Loan supplier	Nou Chan Reth	Bank	No loan	Nou Chan Reth	No loan
Loan amount (USD)	44,000	Not given		25,000	
Loan rate (%APR)	14	Not given		0	
Payback (years)	3	Not given		Less than 1	

The average gasifier capacity is 450hph, or 335.6kWh.

Table 31: Gasifier operating characteristics (average hrs)

Running hrs	High season	Low season
Gasifier running hours/day	8.4	4.6
Gasifier running days/week	6.8	4.2

The gasifiers operate at almost the same rate as the generators in the high season (the gasifier and generator are always working together), but operate at a lower rate than the generators in the low season. This could be due to the fact that rice husks become unavailable and more expensive in the low season, so the millers increase their diesel consumption and decrease their use of the gasifier.

The average rice husk feed rate in the gasifier hopper is 295 kg/h. This varies significantly among the four mills who answered this question, from 80 kg/h to a maximum of 600 kg/h.

When the gasifier starts, some fuel is needed to begin the combustion. Three mills use rice straw (only one miller provided the quantity: 0.5kg each time the gasifier is turned on), one mill uses diesel (5L) and the last one uses electricity (400V) to ignite the rice husks in the hopper).

The gasifier is shut down and restarted on average three times a day in the high season, and 1.8 times a day in the low season. Thus, for the mill which uses diesel to start the system, an extra quantity of 420L of diesel per month (in the high season) is required.

Table 32: Diesel fuel consumption with and without gasifier usage*

Diesel Consumption	Mean value High season	Low season
Maximum diesel fuel used (L/day)	189.2	175.6
Minimum diesel fuel used (L/day)	134.8	124.4
Diesel fuel consumption without gasifier (L/day)	355.8	305.8

** Does not include diesel fuel used to start the gasifier*

The table above shows the quantities of diesel needed to run the diesel generators in addition to the gasifier. We asked the miller if they noticed any variation in this quantity (maximum and minimum) within the high and low activity seasons, but only one miller was able to recognize some small variations. The other four simply gave us their average diesel consumptions during the high and low seasons. The daily fuel consumptions without gasifiers are very similar to the results we obtained for the generator fuel consumptions at the other mills. The amount of diesel saved by using a gasifier is 166.6L to 221L per day in the high season, and 130.2L to 181.4L per day in the low season.

One miller said he also uses wood waste as a fuel in the gasifier, but all of the other millers only use rice husks as fuel.

The five millers paid on average USD 62,800 for the gasifier technology (minimum USD 30,000 and maximum USD 154,000). Three millers took out one loan each: two received loans directly from the gasifier supplier (Nou Chan Reth), and one received a loan from a bank. While the miller who borrowed from the bank did not provide the details of his loan, the other two millers with loans borrowed USD 25,000 and USD 44,000, at annual interest rates of 0% and 14% respectively. The payback period for the USD 25,000 loan is less than one year, and three years for the USD 44,000 loan.

Gasifier maintenance costs each mill on average USD 1,325 per year (minimum USD 0 and maximum USD 3,000).

4.2.6. Environmental and health issues

The five millers answered questions related to the potential impacts of their gasifiers on the surrounding environment and their employees' health.

All the millers reported that their gasifiers produce char, tar and sludge waste products. Four millers stated that their gasifiers produce black water and bad smells, and two of the millers noted changes in the local environment due to gas or smoke emissions.

One miller reported that working near the gasifier caused some eye pain for his employees. None of the millers recognized any health problem related to contact with the gasifier waste (char, tar, sludge, wastewater, etc.).

The millers have never had problems with the reactor overheating. However, if there is a problem, only three mills have procedures for fire prevention and fire-fighting (gas and water fire extinguishers). No procedure for the employees, related to their work in contact with the gasifier and waste, was reported.

Char

Only two mills provided their char production: 0.2 tons and 1 ton per day in the high season, and 0.05 tons and 0.2 tons per day, respectively, in the low season. All of the mills have a wet char discharge, which means that water is used in the reactor to quench the reaction. Only two mills sell their char, to farmers who then use it as fertilizer. One mill sells char at 16,600 riel/ton (USD 4.00) and the other sells char at 20,000 riel/ton (USD 5.00).

Figure 16: Char stockpiles

Sludge

Only one miller knew how much sludge the mill produces: 10L per day in the high season, and 2L per day in the low season.

None of the mills have any treatment or waste management procedures for sludge. Two of the five mills store it in ponds with the wastewater, and simply let the ponds discharge into the local environment when they are full. One mill stores it in 30-40L drums, one miller throws it in the field behind his home, and one mill disposes of the sludge when he sells his rice husk char (we do not know how they use the sludge).

Figure 17: Sludge from the bottom of the waste water pond

The millers were also asked about the number of filters that the gasifiers are equipped with, to clean the syngas from the reactor. Three mills have four filters, one mill has two filters, and one mill has six filters. These filters are mostly made of rubber tree sawdust, waste fabric, and rice husks. The filters are changed regularly, from one time per month, to one time every 4-5 days depending on the mill. The old filters are hand washed and reused, burnt, or simply thrown away.

Only two millers had an idea about how much tar they produce: 0.8L and 10L per day, respectively. Three mills throw the tar away or burn it, while the two other mills do not care about this waste. Only one miller stated that his employees have direct skin contact with tar from the gasifier.

Figure 18: Tars from the filters

Black Water

Four of the five mills said that their gasifiers produce waste water ("black water") with the gasification process. They change the water from the gasifier scrubber cycle every 7, 10, 15 and 150 days, respectively. Only one miller knew about the quantity of black water being produced per day: 5L per day in the high season, and 2L per day in the low season. The three other millers did not know the quantities of black water produced.

None of the mills has a water treatment system; they add fresh water to the gasifier from catchment ponds, and let the old water flow away. Considering that the mills are, on average, 6.6km away from a river (minimum 1km, maximum 18km), there is a serious risk that the black water can contaminate a local water source. Moreover, the water table is on average 21.6m deep (minimum 2.5m, maximum 40m), and the soils in the Tonle Sap and Mekong plain areas are sedimentary, which means that it is easy for a pollutant to contaminate the local soil and underground water.

Figure 19: Employee managing the gasifier waste water ("black water")[44]

Gas

None of the five mills are concerned about the potential gas emissions from the gasifier reactor, but four of them admit that the gasification process generates a bad smell. However, nobody has ever complained to the millers about this problem.

Two mills noticed some change in the surrounding environment after using the gasifiers: a bad smell; black tar spreading on the surrounding fields; and, occasionally smoke filling the immediate mill area. Only one mill found a solution; to dig a containment pit so that the tar could not spread into the neighbouring area.

Although one mill spent USD 15, in general the millers do not spend money for environmental issues, and health and safety problems.

[44] Note that no safety equipment is worn.

Figure 20: Environmental impact: char, sludge, tar and black water released into the environment

4.2.7. Data collection, record keeping and data management

The figure below summarizes the millers' data collection practices. All of the millers collect data on finances, which is consistent with the results for the 30 mills without gasifiers. Three mills also collect information about employment, milling activities and energy consumption. None of the millers record any data about the potential environmental impacts or health and safety issues of their mills.

Most of the time, the mills started data collection in the same year they began operations. But the mills which opened in 1987 and 2009 only started collecting data since 2007 and 2011, respectively. Only one mill has an electricity meter, which is never read.

Four of the five mills do not proceed to manage or analyse their collected data. One mill uses statistical analysis to improve its milling activity and financial benefits. Only one mill agrees to exchange data, and then only with the Cambodian government.

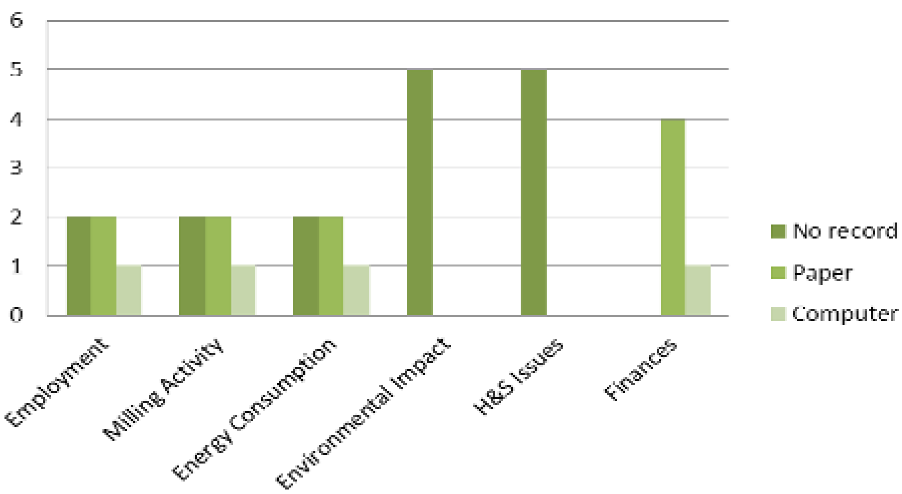

Figure 21: Data collection

The results presented in this section have been used to carry out the Feasibility Assessment (Chapter 5) and the Environmental Impact Assessment (Chapter 6).

4.3. Standardized Baseline

The "standardized baseline" for a CDM project activity is defined as ‘’A baseline established for a Party or a group of Parties to facilitate the calculation of emission reduction and removals and/or the determination of additionality for clean development mechanism project activities, while providing assistance for ensuring environmental integrity.’’[45]

The Cambodian DNA submitted a proposal for a Standardized Baseline for the Rice-husk Sector in Cambodia to the Executive Board in September 2012. In December 2012 the Executive Board successfully concluded an Initial Assessment of the Standardized Baseline submission.[46]

The Executive Board’s decision on whether to approve the Standardized Baseline or not will be posted in mid 2013 on the CDM Website:
https://cdm.unfccc.int/methodologies/standard_base/index.htm

[45] CDM Rule Book, Baseline [Online] Available at: http://cdmrulebook.org/164
[46] https://cdm.unfccc.int/methodologies/standard_base/index.html

5. Results: Feasibility Study

Chapter five summarizes results from the Feasibility Study. The results are presented in five sections

1. Eligibility Assessment (¶ 5.1)
2. Preliminary Emission Reductions Calculations (¶ 5.2)
3. Financial Analysis of the project (¶ 5.3)
4. Gap Analysis (¶ 5.4)
5. Road Map (¶ 5.5)

In this chapter the wording ''project proponent''[47] refers to SNV or any other organization that is responsible for the design and implementation of the project.

5.1. Eligibility Assessment

Eligibility of the Waste to Energy project for the Rice Milling sector to be developed as a carbon project in the host country of Cambodia has been assessed against the following five criteria:

1. Suitable carbon standard and methodology;
2. Prior consideration;
3. Project start date;
4. Additionality;
5. Official Development Aid (ODA).

5.1.1. Suitable carbon standard and methodology: CDM standalone project

The Clean Development Mechanism (CDM) requires application of a baseline and monitoring methodology in order to determine the amount of Certified Emission Reductions (CERs) generated by a mitigation project in a project host country. Methodologies are classified into four categories:

- Methodologies for large scale CDM project activities;
- Methodologies for small scale CDM project activities;
- Methodologies for large scale afforestation and reforestation (A/R) CDM project activities;
- Methodologies for small scale A/R CDM project activities.[48]

The present project falls in the second category: methodology for small scale CDM project activities given the non-industrial application of rice-husk technology.

Additionally carbon methodologies are grouped in the so-called sectorial scope. There are 15 sectorial scopes.[49] The relevant scope for this rice-husk waste to energy project is sectorial scope 1: *Energy industries (renewable - / non-renewable sources).*

Sectorial scope *Energy industries (renewable - / non-renewable sources)* comprehends many methodologies based on the type of mitigation activity.

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[47] CDM Rule Book [Online] Available at: http://cdmrulebook.org/69.
[48] UNFCC (2012) *CDM Methodology Booklet* [Online] Available at: http://cdm.unfccc.int/methodologies/index.html
[49] http://cdm.unfccc.int/DOE/scopes.html

AMS-I.A, AMS-I.B, and AMS-III.E have been identified as suitable methodology to quantify diesel displacement in the current project scenario and avoidance of methane emissions during rice-husk decay:

1. AMS-I.A: involve renewable energy technologies that supply electricity to local grid;
2. AMS-I.B: involve renewable energy technologies that supply mechanical energy;
3. AMS-I.D: involve renewable energy technologies that supply electricity to national grid;
4. AMS-I.E: to quantify avoided methane emissions from biomass decay;

Baseline study results confirmed that 81.3% of the millers without RHG system interviewed are using generators to produce mechanical energy, 12.5% produce electrical energy and 6.3% produce both. All of the generators owned by mills with RHG deliver mechanical energy to the mill (§ 4).The results shows that only 26.7% (n=8/30) of the mills without RHG are connected to the grid, thus ruling out the option of using AMS.I.A and AMS.I.D. This is confirmed by SNV baseline study results[50]. The gasification technology is to be therefore be used to supply mechanical energy to the mill for milling operation. No electricity will be sold to the local or national grid.

AMS-III.E is to quantify emissions from rice-husk decay. This methodology is only applicable when:

- the biomass would have otherwise been left to decay under clearly anaerobic conditions throughout the crediting period in a solid waste disposal site without methane recovery;
- the biomass is already deposited in a waste disposal site without methane recovery.

Despite the fact that there is a precedent project in Cambodia using this approach the baseline study shows that the millers do not dispose rice husk in a system that is clearly anaerobic and it is not deposited in a waste disposal as the methodology states. It is therefore very difficult to quantify avoided methane emissions from rice husks decay. (§ 4)

AMS-I.B is therefore the most appropriate CDM carbon methodology for a rice-husk gasification project in Cambodia.

Nexus also assessed the possibility of using methodologies available within the scope of voluntary carbon standards, such as Gold Standard (VGS). No suitable methodologies for the development of a rice-husk carbon project exist. In the likelihood that a voluntary carbon project is to be developed CDM methodologies can be used.

In section 5.2 emissions from displacement of diesel are be therefore calculated using the latest version of CDM AMS.I.B Methodology within the context of a CDM/VGS standalone project.

5.1.2. Suitable carbon standard and methodology: CDM Programme of Activities

Programme of Activities (PoA) is a "voluntary coordinated action by a private or public entity which coordinates and implements a policy/measure or stated goal which leads to additional GHG emission reductions that occur via an unlimited number of CDM program activities (CPAs)"[51].

The PoA approach achieves economies of scale by enabling many similar projects to be incorporated under one registration procedure. A PoA differs from the traditional stand-alone CDM/VGS project

[50] Sophorn, Ngy (2012) Baseline Study, Waste to Energy for the Rice Milling Sector in Cambodia, SNV, p 12.
[51] CDM Rule Book, [Online] Available at: http://cdmrulebook.org/1021

mainly by its operation. Programmatic CDM occurs at two levels - at the Programme level and at the Activity level.

- The Programme level refers to the overall umbrella programme that manages the implementation of the activities under the PoA. The Programme Level is coordinated by the Coordinating/Managing Entity, which can be a private or public entity that implements policies, programs or measures that lead to real GHG emission reductions. The main Purpose of a PoA is to provide the enabling environment - the organizational, financial and methodological framework- for others to implement a policy /measure or stated emission reductions goal at the level of the CPAs. The PoA does not actually achieve the emission reductions since those are attained at the CPA level;
- The Activity Level refers to the small individual projects that are known as the CPAs, or CDM Programme Activity. Each CPA consists of an activity that achieves GHG emission reductions or removal by sink, using CDM methodologies.

The Programme of Activities is implemented via an unlimited number of CPAs, which consist of a multitude of GHG reduction activities occurring over time in a single or multiple sites. These sites could be located within one or more cities, regions, or countries, as long as each country involved submits a Letter of Approval.

The Coordinating/Managing Entity (CME) is responsible for the overall management of the PoA. The CME is responsible for:

- Ensure that CPAs are correctly included in the PoA
- Collect, manage and archive the ER data from every CPAs
- Produce overall monitoring report
- Coordinate with Designated Operational Entities (DOE)

The figure below illustrates how a PoA is organized.

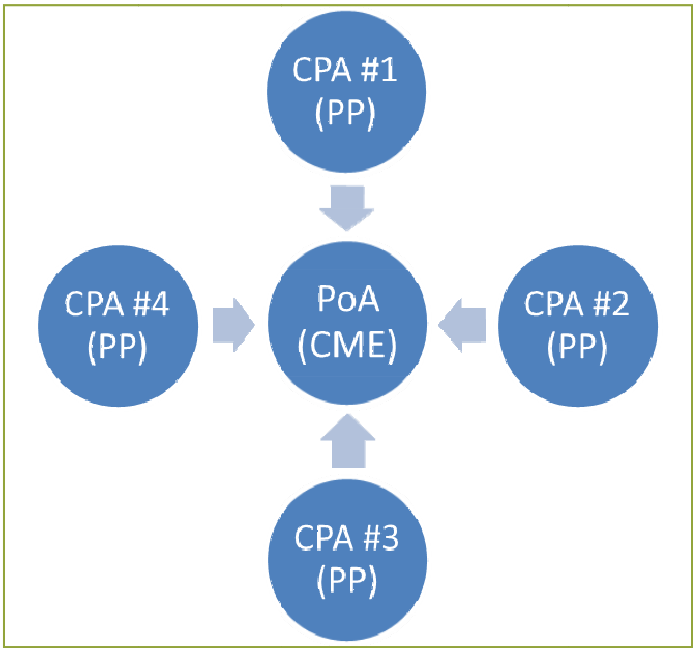

Figure 22: PoA Structure

Advantages

The PoA reduces the overall costs of implementation of carbon projects such as:

- The CPA#2 (and onwards) does not need to go through the registration process at the EB. It only needs to be validated by the DOE and becomes automatically included into the PoA.
- The validation process is simplified because the same type of project has already been validated and only needs to comply with the eligibility criteria set up at the PoA level
- The CPA#2 (and onwards) does not need to provide a new Letter of Approval from the DNA because the PoA already has one.
- The verification process does not verify every CPAs, but CPAs are to be selected using a sampling approach thus reducing the costs of issuance
- All the credits are issued at the same time making the issuance process easier and faster
- Most donors and investors are now interested in investing and helping PoAs
    - Using this option helps raising funds more easily
- There is no risk of contamination from one CPA to the other if something wrong happens, each CPA is fully separated from the other CPAs

Disadvantages

The CDM PoA rules also bring disadvantages to project developers such as:

- Developing a PoA requires more work which means that more time is needed to complete the work which may increase delays in the implementation of the CPA;
- The start date of the CPA can only happen after the start date of the PoA (more information available below);
- If a PoA is operating in several countries, a Letter of Approval from each DNA at the time of validation is needed;
- DNAs may not understand the meaning of PoAs and may be reluctant to sign the Letter of Agreement (LoA).

5.1.3. Suitable carbon standard and methodology: VGS Programme of Activities

The Voluntary Gold Standard Programme of Activities (VPoA) follows the same structure as the CDM-PoA with a few differences as stated below:

- The VPA process goes through the GS and therefore the process is simpler and faster than going through the EB CDM;
- There is no need to produce LoAs to develop the project and therefore the VPoA could include every country in the world;
- There is no limitations of the countries to be included, therefore countries such as Thailand, Vietnam, China, India are be eligible to under the VPA;
- The VPoA accepts retroactive projects.

Each VPoA includes Voluntary Project Activities (VPAs) which are the same as CPAs. New VPAs do not need to go through the 2 months GS Technical Review requirement and would be automatically included under the VPoA once the validation process is completed.

The programmatic approach is interesting in terms of the WtE project because it doesn't a pre-determined number of project participants, in this case rice mills. This may suit the existing initiative which looks to establish the appropriate framework for a sustainable gasification sector. By registering the concept for converting waste to energy, individual millers would be able to join over time.

A follow up study on the feasibility of PoA is to be carried out in March 2013. The objective is to develop a Conceptual Development Study and a Project Idea Note (PIN) to inform the development of a CDM PoA on rice husk gasification in Cambodia. For this reason, the present work mainly focuses its attention on the potential of developing a standalone project, CDM or VGS, rather than a PoA.

5.1.4. Prior Consideration

The project proponent needs to demonstrate that the carbon finance route has always been considered since the inception of the carbon project. Evidence must indicate that there was awareness of the CDM prior to the project activity start date and that the benefits of the CDM were a decisive factor in the go/no-go decision to develop the carbon project. Evidence to support prior consideration would include, inter alia, minutes and/or notes related to the consideration of the decision by the Board of Directors, or equivalent, of the project participant, to undertake the project as a proposed CDM project activity. In addition reliable evidence from project participants that indicates that continuing and real actions were taken to secure CDM status for the project in parallel with its implementation is to be submitted to the CDM Executive Board (EB). [52]

In case the project proponent is to develop a Rice-Husk Gasification PoA, a prior consideration form is not to be submitted.[53]

At the time of writing a lack of carbon project design and a defined project proponent has been identified. Once the project proponent is defined and the decision to go ahead with the development of a carbon project is made, relevant documentation (as above) needs to be submitted to the CDM EB. The lack of project design and defined project proponent has confirmed by SNV WtE project management and by the EU-Switch Asia proposal.[54]

Nexus recommendation is for SNV to send a prior consideration form to the Designated National Authority (DNA) of the host country, i.e. Cambodia and to the UNFCCC secretariat. The form is to be used by project participants in order to submit the notification of the commencement of the project activity and the intention to seek CDM status. (Annex 2). Such notification must be made within six months of the project activity start date and shall contain the precise geographical location and a brief description of the proposed project activity, using the standardized form F-CDM-Prior Consideration. Such notification is not necessary if a project design document (PDD) has been published for global stakeholder consultation or a new methodology proposed to the Executive Board for the specific project before the project activity start date. If such notification has not been provided, the DOE shall determine that the CDM was not seriously considered in the decision to implement the project activity.

VGS rules do not require the submission of a Prior Consideration form, however it is good practice to submit the form so that it can be used the project start date in case a VGS project is to be developed.

In case the project activity is to be discontinued and the decision is made not to develop a carbon project the submitted prior consideration form can be withdrawn by the project proponent.

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[52] CDM Rule Booklet, Additionality [Online], Available at: http://cdmrulebook.org/165
[53] EB.66, Annex 64
[54] Contracting Authority: European Commission SWITCH-Asia Promoting Sustainable Consumption and Production Grant Application Form Budget Line: 19.100101 Reference: EuropeAid/130830/C/ACT/CAI, p 19

5.1.5. Project Start Date

In the context of a CDM project activity[55] the project start date is defined as *''the earliest date at which either the implementation or construction or real action of a CDM project activity begins."*

VGS provides more flexibility into the definition of the start date and accepts that the starting may have happened in the past, and can generate credits retroactively.

Selecting an appropriate starting date is crucial as there needs to be clear evidence of prior consideration that carbon finance is required to implement the project. (see ¶ 5.1.4). At the time of writing there is not clear indication of the project start date due to lack of project design and a defined funding source/grant funding to subsidized installation of the new Rice-husk gasification. The selection of the appropriate start date determines the date from which emissions reductions can accrue.

5.1.6. Additionality

According to CDM Additionality Guidelines for Small Carbon Projects[56], certain grid-connected renewable electricity generation technologies are automatically considered as additional. Nexus assessed the criteria (Table 33) of automatic additionality against the characteristics of the current WtE Project for the Rice Milling Sector in Cambodia to see whether there is likelihood that the automatic additionality could be applied.

Table 33: Automatic additionality criteria

Automatic Additionality Criteria	Compliance WtE Project	Comments
a. Grid-connected renewable electricity generation technologies of installed capacity up to 15 MW;	Not compliant;	The WtE project cannot be defined as an electricity generation project. Mechanical energy to power the mills is to be produced thanks to the gasification units;
b. Off-grid electricity generation technology, where the individual units do not exceed the thresholds indicated in parentheses with the aggregate project installed capacity not exceeding 15 MW: Biomass gasification/biogas (up to 100 kW)	Not compliant;	The mills to within the scope of the WtE project for the Rice Milling Sector in Cambodia has individual capacity higher than 100 kW; RHG to be installed range from 150 kW to 600 kW;
c. Project activities solely composed of isolated units where the users of the	Not compliant;	As per current SNV installation plan the aggregated capacity of the RHG units is larger than

[55] Glossary CDM Terms, Version 7.0. [Online] Available at http://cdm.unfccc.int/Reference/Guidclarif/glos_CDM.pdf

[56] ''Guidelines for Demonstrating Additionality of Certain Small-Scale Project Activities'' [Online] Available at http://cdmrulebook.org/166

technology/measure are households or communities or Small and Medium Enterprises (SMEs) and where the size of each unit is no larger than 5% of the small-scale CDM thresholds;		5% of the small-scale CDM threshold, i.e. 15000 Kw. (calculations in Table 34)
d. Rural electrification project activities using renewable energy sources in countries with rural electrification rate is less than 20%;	Not compliant;	The WtE project for the Rice Milling Sector in Cambodia cannot be classified as a rural electrification project;
e. A project activity that is indentified as a first-of-its-kind[57] project activity is additional, however its crediting period can only be for a maximum of 10 years with no option of renewal.	Not compliant;	The project is not be a first-of-its-kind as there is another RHG gasification project in Cambodia;

Criteria **c** in the table above sets that a project is automatic additional when the total aggregated capacity is no larger than 5% of the CDM small-scale threshold. As per CDM Methodology AMS.I.B the ''aggregate installed capacity after adding the new units or installed capacity of the more efficient units should be lower than 15 MW[58].''

Table 34: WtE Aggregated installed capacity

RHG Scale	MIN RHG Capacity	MAX RHG Capacity	RHG to be installed	RHG to be installed	Aggregated Install Capacity MIN	Aggregated Install Capacity MAX
-	*kW*	*kW*	*(%/tot)*	*(n/yr)*	*Kw*	*Kw*
Small	200	350	90	135	27000	47250
Medium	350	600	5	7	2450	4200
Large	700	900	5	8	5600	7200
Tot	-	-	-	**150**	**35050**	**58650**

At the time of writing there is not clear project design including RHG installation and dissemination plan. Nexus recommendation is for the project proponent, once the plan is available, to assess whether it is compliant or not with criteria of automatic additionality. Applying automatic additionality shortens the process of PDD-writing and Validation by DOE as a full additionality assessment does not need to be developed.

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[57] A proposed project activity is the first-of-its-kind in the applicable geographical area if: The project is the first in the applicable geographical area that applies a technology that is different from any other technologies able to deliver the same output and that have started commercial operation in the applicable geographical area before the state of the project. [Online] Available at: http://cdmrulebook.org/166;

[58] Ex: 5 MW of new capacity is added to existing 9 MW to make the aggregate capacity of 14 MW which is within the allowed limits 15 MW capacity.

In case the project does not comply with automatic additionality, additionality of the carbon project needs to be demonstrated with one of the following Barrier Analysis. The Project Proponent has to select which would be the most relevant barrier that would impede the development of a WtE project if carbon finance was not to be put into place:

1. Investment Barrier: a financially more viable alternative to the project activity would have led to higher emissions; Best practice examples include but are not limited to, the application of investment comparison analysis using a relevant financial indicator, application of a benchmark analysis or a simple cost analysis (where CDM is the only revenue stream such as end-use energy efficiency). It is recommended to use national or global accounting practices and standards for such an analysis.

2. Access-to-finance Barrier: the project activity could not access appropriate capital without consideration of the CDM revenues; Best practice examples include but are not limited to, the demonstration of limited access to capital in the absence of the CDM, such as a statement from the financing bank that the revenues from the CDM are critical in the approval of the loan.

3. Technological Barrier: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions; Best practice examples include but are not limited to, the demonstration of non-availability of human capacity to operate and maintain the technology, lack of infrastructure to utilize the technology, unavailability of the technology and high level of technology risk.

4. Barrier due to prevailing practice: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions; Best practice examples include but are not limited to, the demonstration that project is among the first of its kind in terms of technology, geography, sector, type of investment and investor, market etc.

5. Other barriers such as institutional barriers or limited information, managerial resources, organizational capacity, or capacity to absorb new technologies (EB 35, Annex 34, paragraph 1).

Additionality needs to be demonstrated by the project proponent by providing transparent and documented third party evidence such as national/international statistics, national/provincial policy and legislation, studies/surveys by independent agencies etc.

For example in Project Development Document (PDD) of the *Angkor Bio Cogen Rice Husk Power Project*[59], a CDM RHG project registered in 2006, the following barriers were identified:

- Barrier due to prevailing practice: ''There are currently no regulations for the management of rice husk. It is unlikely that new regulations are introduced during the crediting period to require Angkor Rice Mill to change its current practice. There is also no standard technology available to manage rice husk. It is a normal practice in Cambodia to leave rice husk outside

[59] http://cdm.unfccc.int/Projects/DB/DNV-CUK1144657688.42/view

until it is naturally decomposed. It is apparent that without incentives in the forms of carbon credits, Angkor Rice Mill will continue the current practice.''[60]

- Technological barrier: ''The Project represents the first case of applying the rice husk-fired power generation technology in Cambodia. (...)While the technology has a proven track record of combusting rice husk for power generation, it is by no means guaranteed that the technology will not encounter unforeseen problems when it is applied to rice husk in Cambodia with their particular characteristics. Due to its high mineral content and composition, rice husk has a tendency to produce slag when the combustion temperature is not well controlled. Local staff will have to undergo extensive training to ensure adequate combustion temperature. Training must also be extended to cover ash disposal and other matters relating to the proper operation of the power plant, notably water treatment. The careful control and monitoring of the water quality needed for a high-pressure boiler system to prevent problems with the boiler and with the turbine blades requires training for a skilled technician. A proper maintenance is essential especially since in case that the power plant is damaged, there will not be spare parts that will be immediately available in Cambodia. The application of the new technology for the first time in the country will be too risky to implement without financial assistance through obtaining CERs.''[61]

Due to the above barriers the implementation of *Angkor Bio Cogen Rice Husk Power Project* would have been impossible without the CDM; as a consequence the project proponent was able to demonstrate additionality of the project. Barrier due to prevailing practice is still valid.

In case a carbon project is to be developed within the WtE project for the Rice Milling sector in Cambodia, the project proponent can use the above mentioned PDD as a reference to demonstrate additionality of the project.

However, it should be noted that the EU-Switch Asia proposal explicitly mentions that carbon finance is not part of the initial project, but the present Feasibility Assessment. The EU-Switch Asia funding has the objective of installing 150 gasifiers explicitly without carbon finance. In order to demonstrate additionality of the project a clear decision needs to be made on what the purpose of carbon finance is for. This could either to improve affordability of gasifiers for millers (e.g. carbon finance is used to subside part of the RHG) or for the scale up of the project beyond the scale of the present proposal. Without this the existing project would not be considered additional.

5.1.7. Official Development Aid

As part of the CDM core requirements to develop a carbon project, the Project Proponent has to make sure that carbon finance for the development of a project is not to not to result in the diversion of official development assistance (ODA)[62] by donors agencies at all levels.[63] In the likelihood that a carbon project is to be developed in the context of WtE the Rice Milling Sector in

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[60] http://cdm.unfccc.int/filestorage/F/U/E/FUE7N0HHQBYQLNF2SMO8B17GFBPQZ1.1/ABC_PDD_2006-04-10.pdf?t=TDl8bWhvYmZsfDDg63gLdmL2iFQLuroy0N5M

[61] http://cdm.unfccc.int/filestorage/F/U/E/FUE7N0HHQBYQLNF2SMO8B17GFBPQZ1.1/ABC_PDD_2006-04-10.pdf?t=TDl8bWhvYmZsfDDg63gLdmL2iFQLuroy0N5M

[62] Flows of official financing administered with the promotion of the economic development and welfare of developing countries as the main objective, and which are concessional in character with a grant element of at least 25 percent (using a fixed 10 percent rate of discount). By convention, ODA flows comprise contributions of donor government agencies, at all levels, to developing countries ("bilateral ODA") and to multilateral institutions. ODA receipts comprise disbursements by bilateral donors and multilateral institutions (*OECD Glossary of Statistical Terms*).

[63] CDM Rule Booklet, ODA [Online], Available at http://cdmrulebook.org/758

Cambodia, the project proponent needs to sign a declaration that no ODA has been deviated to finance the carbon project. ODA Declaration template is available on the Gold Standard website and can be found in Appendix 3.

At this stage there is not clear project design and therefore no specific organization a/o stream of funding has been clarified. Therefore Nexus cannot advise whether the identified funding stream is complaint with ODA requirements.

Nexus recommendation with regards to Feasibility Study: Official Development Aid is to consult ODA UNFCCC Guideline (http://cdmrulebook.org/758) and to fill the ODA Declaration (Appendix 3) making sure that the identified funding sources are complaint with ODA requirements.

5.2. Preliminary Emission Reductions Calculations

Nexus has used CDM AMS.I.B Methodology to assess the carbon potential of a rice husk gasification project in Cambodia in terms of Emission Reductions (ERs). Nexus calculated ERs for CDM and VGS standalone project scenarios. **It is important to notice that at this stage ERs are estimates** which were calculated using the data collected during the Baseline Survey [December 2012] and the data reported in SNV Baseline Study [June 2012]. The baseline emissions are calculated by estimating the emissions from serving the same load, as provided by the gasifier units, with a diesel generator. The table below summarizes the assumptions on which the ERs calculations were based upon.

The emissions reductions were calculated using a conservative approach based on the interpretation of the CDM AMS.I.B methodology in similar projects. Total ERs (table 38 and 39) give therefore an indication of the minimum amount of ERs that could be accrued thanks to the development of the project.

Table 35: Assumptions (ERs Calculations)

Description	Value	Unit	Reference
Conversion factor (hph to KW)	0.7457	KW	http://www.nist.gov/pml/pubs/sp330/index.cfm;
Diesel Emission Factor (Kg CO_2/Kg Diesel)	3.2	CO_2e	Default Value IPCC;
Number of days in a solar year	365	days	-
Number of months in a solar year	12	months	-
Number of weeks in a solar year	52	weeks	-
Emission Factor Diesel (kg CO_2e/kWh)	0.8	kg CO_2e	AMS.I.D, Table I.D.I under category I.D;
Conversion factor (kg to tonnes)	1000	Kg	-
Diesel Density	0.832	-	Default Value IPCC;
Running hrs RHG (average)			
Number hrs per day	6.50	hr	Baseline Survey, 2012;
Number days per month	23.83	day	Baseline Survey, 2012;
Number months per year	8.25	month	Baseline Survey, 2012;
Number days per year	196.63	days	Baseline Survey, 2012;
Diesel Consumption (average)			
Usage Diesel (l/hph)	84.40	l	Baseline Survey, 2012;

RHG Preliminary Installation Plan (SNV)			
Small Scale RHG (MIN 200 - MAX 350 KW)	135	RHG Unit	Interview key SNV staff;
Medium and Large Scale RHG (MIN 350 – MAX 900)	15	RHG Unit	Interview key SNV staff;
Tot RHG to be installed	120	RHG Unit	Interview key SNV staff;
Tot RHG to be upgraded	30	RHG Unit	Interview key SNV staff
Carbon Project Development Timeline			
Assumed Registration Date	June 2014		Nexus Team Assumption due to lack of precise data;

The tables below show baseline emissions and potential emissions reductions from different sized gasifiers.

Table 36: Baseline emissions (t/CO_2)

Gasifier Capacity (hph)	Gasifier Capacity (KW)	Operation RHG (hrs/yr)	Gasifer Capacity (KWh)	Diesel Emission Factor	Baseline Emissions (tCO_2e/yr)
200	149.14	1182	176297	0.8	141.04
250	186.42	1182	220371	0.8	176.30
300	223.71	1182	264445	0.8	211.56
350	260.99	1182	308520	0.8	246.82
400	298.28	1182	352594	0.8	282.07
500	372.85	1182	440742	0.8	352.59
600	447.42	1182	528891	0.8	423.11
900	671.13	1182	793336	0.8	634.67

Table 37: Project emissions t/CO_2)

Gasifier Capacity (hph)	Gasifier Capacity (KW)	Operation RHG (hrs/yr)	Gasifer Capacity (KWh)	Diesel Usage (l/yr)	Diesel (Kg/yr)	Project Emissions (t CO_2e/yr)
200	149.14	1182	176297	16881	14045	44.94
250	186.42	1182	220371	21101	17556	56.18
300	223.71	1182	264445	25321	21067	67.42
350	260.99	1182	308520	29542	24579	78.65
400	298.28	1182	352594	33762	28090	89.89
500	372.85	1182	440742	42202	35112	112.36
600	447.42	1182	528891	50643	42135	134.83
900	671.13	1182	793336	75964	63202	202.25

Tables 38 and 39 below shows how the different estimates under the different scenarios (CDM and VGS) compare to each other. More accurate ERs can be calculated once a clear RHG installation plan has been devised by the project proponent. The existing calculations are based on a dissemination of 150 gassifiers over four years, or around 3 per month. The calculations also assumed a split between the sizes of the digesters of 9:1 of small to medium RHG. At the time of writing due to a lack of detailed RHG installation plan, a provisional installation plan has been taken into account (Table 34).

Table 38: Summary of CERs (tCO_2e)

CER Estimates		
Year	Cumulative RHG Units in use (n/yr)	Cumulative ER/yr (tCO_2e)
Feb 2013-May 2014	50	-
Jun 2014-May 2015	90	19,535
Jun 2015-May 2016	135	32,604
Jun 2016-May 2017	150	40,249
Jun 2017-May 2018	150	41,146
Jun 2018-May 2019	150	41,146
Jun 2019-Jan 2020	150	27,430
Tot ER (tCO_2e)		**202,109**
Average annual (tCO_2e)		**28,872.66**

Table 39: Summary of VERs (tCO_2e)

VER Estimates		
Year	**Cumulative RHG Units in use (n/yr)**	**Cumulative ER/yr (tCO_2e)**
Feb 2013-Jan 2014	42	6,073
Feb 2014-Jan 2015	70	15,840
Feb 2015-Jan 2016	123	28,504
Feb 2016-Jan 2017	150	38,583
Feb 2017-Jan 2018	150	41,146
Feb 2018-Jan 2019	150	41,146
Feb 2019-Jan 2020	150	41,146
Tot ERs (tCO_2e)		**212,438**
Average annual (tCO_2e)		**30,348.17**

It can be noticed that the total ERs in VGS scenario are slightly higher than CERs scenario (10,320 tCO_2). This is due to the fact that in the Voluntary Gold Standard scenario, the project proponent can retroactively claim credits that were accrued before the project registration date. In contrast in the CDM scenario no credits accrued before the project registration date can be claimed. Nexus assumed the project registration date to be in June 2014.

The attached ER spreadsheet has been built as a tool which can be revised fairly simply by updating the relevant tabs with more accurate information (e.g. number of RHG). The total number of ERs will then be updated automatically in the "Summary tab". The spreadsheet provides a range of carbon credits that can be accrued each year in case the project is developed. This range was used to determine project revenues in the Financial Analysis of the project.

5.3. Financial Analysis of the Project

It has been assumed that SNV Cambodia or the project proponent entity that is to be nominated will not receive any revenue from the sales of the Rice Husk Gasifier. Given the lack of project design and identified funding stream, Nexus assumed that from year 2012-2015, the carbon project is being funded with the grants .From year 2015 onwards, Nexus assumed that the target number of digesters is to be installed and therefore no further implementation costs have taken into consideration. It should be noted that based on the existing business plan there is €170K in grants that have not yet been allocated.

Table 40: Profit and loss (P/L) of SNV Cambodia WtE (without carbon finance)

					Projection				
Full budget	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Project revenues									
Grants (SECURED) EU SWITCH	529,569	1,182,723	190,255	0	-	-	-	-	-
Grants (SECURED) SNV Contribution	19,595	19,595	19,595	19,595	-	-	-	-	-
Grants (SECURED) Foundation Ensemble	25,000	50,000	50,000	24,763	-	-	-	-	-
Grants (SECURED) Partners Contribution	5,465	5,465	5,465	5,465	-	-	-	-	-
S/Total Project revenues	**579,628**	**1,257,782**	**265,314**	**49,822**	**0**	**0**	**0**	**0**	**0**
Project costs	-								
SNV HR costs	225,415	226,619	231,502	231,502		0	0	0	0
Travel costs	5,500	5,500	5,500	5,500	0	0	0	0	0
Equipment and supplies	227,949	2,400	0	0	0	0	0	0	0
Local office	14,400	14,400	42,000	42,000	0	0	0	0	0
Other costs and services	91,000	66,400	130,955	130,955	0	0	0	0	0
International and national consultancies	16,100	138,000	64,200	64,200	0	0	0	0	0
S/total project costs	**580,364**	**453,319**	**474,156**	**474,156**	**0**	**0**	**0**	**0**	**0**
P/(L)	(736)	804,463	(208,842)	(424,334)	0	0	0	0	0
P/(L) CUMULATIVE	(736)	803,727	594,885	170,551	170,551	170,551	170,551	170,551	170,551

5.3.1. Transaction cost: carbon finance initial cash outlay

Transaction costs are frequently identified as a major barrier to project development. In particular, development practitioners are adversely affected by the high transaction costs and long lead times associated with the certification process (because of their limited access to appropriate expertise and financial resources).The four stages of project development and associated transaction costs are listed in the table below.

Table 41: Projects stages and associated transaction costs

Stage	Description	Type of cost
Project Design Document (PDD)	One-off costs to prepare documentation detailing the technical and organizational aspects of the project. This phase includes Gold Standard Pre-Feasibility Assessments costs.	Human Resources Baseline studies
Validation by a DOE	A third party, the Designated Operational Entity (DOE) audits the PDD to evaluate if the project matches the requirements of the applicable standard.	Human Resources DOE Gold Standard costs Equipment, surveys
Conducting monitoring activities	Collection of all data necessary for proving emissions reductions	Human Resources Equipment, surveys
Verification by a DOE	Periodic independent review and ex-post determination of the monitored GHG emission reductions	Human Resources DOE Gold Standard costs

Nexus assessed transaction costs associated with the development of a carbon project within the scope of a WtE project for the Rice Milling Sector in Cambodia. Carbon finance only starts to generate revenues after the carbon credits are issued and sold. There are different transaction costs for different routes to the carbon market. Initially, carbon finance incurs large transaction costs in the range of €49K-€64K per annum. These costs are assumed to be the same until 2020. Because at the time of writing a clear project plan is not available, the calculations were based on transaction costs developed for similar projects. The tables below represent the comparison of the two market options which include Voluntary Gold Standard and Clean Development Mechanism. It is observed that CDM route entails a higher transaction cost than VGS route in the first year but the costs are similar for both standards subsequently. Costs of verification are forecast to decrease over time as the, it consists of repeat work.

Table 42: Calculated transaction costs: CDM Scenario

Steps	Description	Year 0	Year 1	Year 2
HR Costs	Project Documentation	34782	-	-
	Validation	17634	-	-
	Verification	-	30735	28485
Other Cost	DOE	25000	20000	20000
	CDM EB	-	1591	711
	Equipment & Survey Costs	2000	5000	7000
	Flights (Travel costs)	3500	3500	3500
Total		**82916**	**60826**	**59696**

Table 43: Calculated transaction costs: VGS Scenario

Steps	Description	Year 0	Year 1	Year 2
HR Costs	Project Documentation	35907	-	-
	Validation	18828	-	-
	Verification	-	31479	28485
Other Cost	DOE	-	20000	20000
	Gold Standard	900	2691	3350
	Equipment & Survey Costs	2000	5000	7000
	Flights (Travel costs)	3500	3500	3500
Total		**61135**	**62670**	**62335**

5.3.2. Carbon finance cash flow

Carbon finance generates long-term profitability for the VGS option, but CDM option is expected to record cumulative losses during the period of analysis (2013-2021). The project does not receive any grant for carbon finance. More grants are needed to reduce the registration risk at the early stage so as to unlock the long-term potentials for carbon finance, especially for the VGS option.

As shown in the figure below, both VGS and CDM options are expected to incur initial losses. From February 2018-2021, it is noteworthy that VGS is expected to generate cumulative net revenues of up to €448K. However, CDM is expected to record cumulative losses, which will peak at €199K, until 2021.

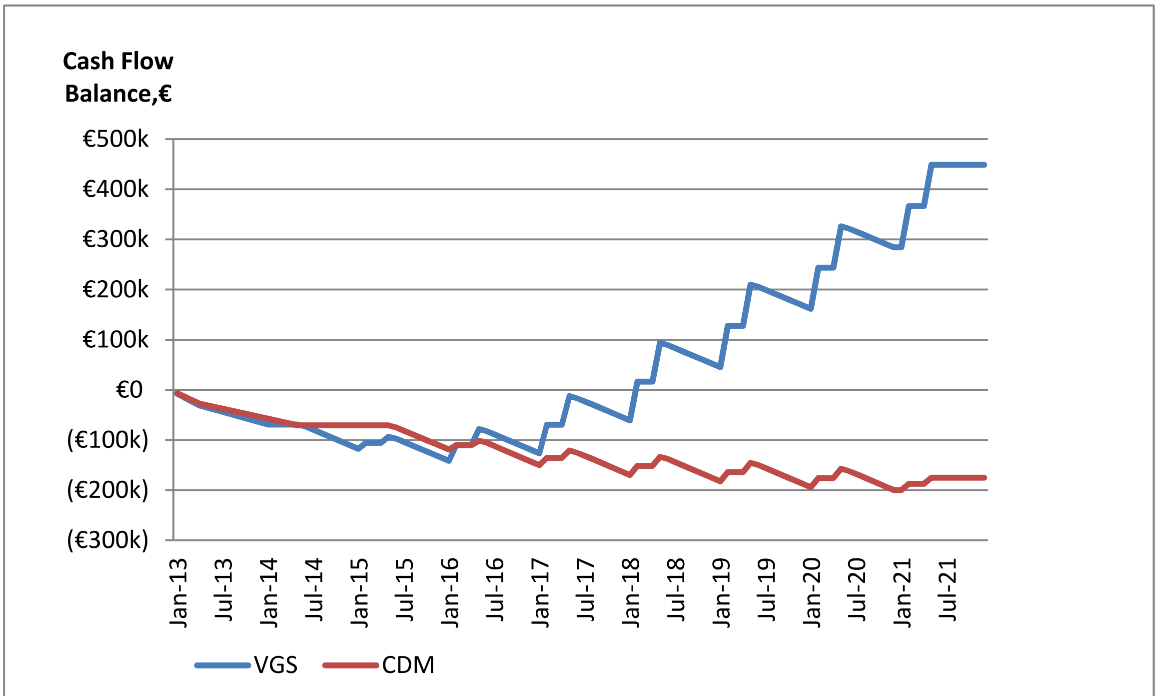

Figure 23: Carbon Finance Cash Flow Balance of Different Options (Jan 2013-Dec 2021)

5.3.3. Breakeven ER prices

As shown in Figure 24, the ER breakeven prices of the project are relatively low due to the presence of the large amount of grants and the moderate ER yield from each RHG. Comparatively, the carbon finance and project costs are covered at a lower ER price via the VGS option, which is €1.02 for VGS and €1.16 for CDM. The higher breakeven prices of CDM are attributed to the lower ER yield and the longer credit issuance process from CDM. Overall, the breakeven price is far below the current market price of €4 per ER for VGS, while it is slightly higher than the market price of €0.90 per ER for CDM.

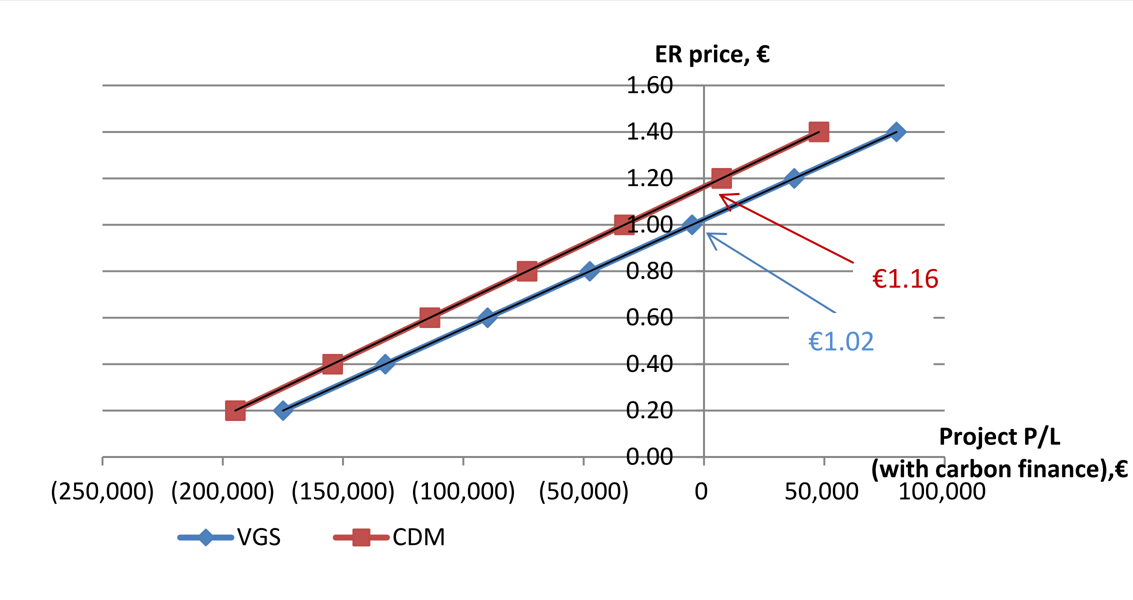

Figure 24: Breakeven price of different carbon finance route

5.3.4. Breakeven RHG units

Table 44 and 45 represent the yearly breakeven RHG units for VGS and CDM options. The ratio of 9:1 is used for the calculation of small to medium RHG. Table 44 and 45 show the minimum project size to breakeven under both VGS and CDM. The negative units in year 2013 are for illustration purpose. In year 2013, the large amount of grants received results in profit for that year. Hence, this serves as a buffer, at the discretion of SNV Cambodia, to slightly reduce the breakeven units of RHG after year 2013.

VGS option requires less RHG units than CDM option to breakeven. Every year, VGS option requires an average of 32 RHG, while CDM option requires a yearly average of 154 RHG to cover the cost. The higher number of units under the CDM reflects the present low price of CER's. Hence, a project disseminating more than this number of units is to generate net revenue for the underlying project

Table 44: Breakeven units of RHG for VGS standalone option

VGS Standalone	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average gasifier per year
Total Number of Gasifier to be installed	1	(1,001)	341	627	64	64	64	64	64	32
Small RHG	1	(900)	307	564	58	58	58	58	58	29
Medium RHG/Large RHG	0	(100)	34	63	6	6	6	6	6	3

Table 45: Breakeven units of RHG for CDM standalone option

CDM Standalone	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average gasifier per year
Total Number of Gasifier to be installed	4	(4,361)	1,514	2,788	288	288	288	288	288	154
Small RHG	4	(3,925)	1,362	2,509	259	259	259	259	259	139
Medium RHG/Large RHG	0	(436)	151	279	29	29	29	29	29	15

5.3.5. Total cumulative P/L

Table 46 and 47 summarize the cash flow balances for the underlying project as well as the different routes to the market (i.e. VGS and CDM). It shows that the VGS route generates cumulative profit of €632K, while CDM route still incur cumulative losses of €53K. This is because carbon finance using the VGS option starts to generate cumulative profits from year 2018 onwards. Also, there is no cost incurred for the underlying project after year 2015. On the contrary, CDM option is expected to incur cumulative losses until 2021. VGS is to record a yearly working capital deficit of €257K-€448K until 2015 but will experience a working capital surplus of €15K-€164K through 2021.
For CDM, there will be a yearly working capital deficit of €11K-€473K but a working capital surplus of €24K in year 2021.

Carbon finance revenues via VGS option generate revenue for the projects during the period of analysis. Therefore, project with VGS option is beneficial if the initial transaction cost are covered to unlock the future carbon finance revenue so as to attain long-term project sustainability.

The conclusions reflect the extremely low price of credits issues through the CDM. In principle credits generated under a UNFCCC approved scheme are lower risk as they are fungible with future market mechanisms. A significant price recovery would alter the recommendation.

Table 46: Carbon finance cash flow balance for VGS standalone

VGS Standalone (In Euro)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Annual ER	-	-	6,073	15,840	28,504	38,583	41,146	41,146	41,146	-
ER stock	-	-	-	6,073	15,840	28,504	38,583	41,146	41,146	41,146
ER sales	-	-	-	6,073	15,840	28,504	38,583	41,146	41,146	41,146
ER revenues	-	-	-	24,293	63,362	114,016	154,332	164,582	164,582	164,582
Transaction costs	-	49,709	48,548	48,288	48,288	48,288	48,288	48,288	48,288	-
Carbon finance P/(L)	-	(49,709)	(48,548)	(23,995)	15,073	65,727	106,044	116,294	116,294	164,582
Carbon finance cumulative P/(L)	-	(49,709)	(98,257)	(122,252)	(107,179)	(41,452)	64,592	180,886	297,180	461,762
Total P/(L)	**(736)**	**754,754**	**(257,390)**	**(448,329)**	**15,073**	**65,727**	**106,044**	**116,294**	**116,294**	**164,582**
Total P/(L) cumulative	**(736)**	**754,018**	**496,628**	**48,299**	**63,372**	**129,099**	**235,143**	**351,437**	**467,731**	**632,313**

Table 47: Carbon finance cash flow balance for CDM standalone

CDM Standalone (In Euro)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Annual ER	-	-	-	19,535	32,604	40,249	41,146	41,146	27,430	-
ER revenues	-	-	-	0	17,581	29,343	36,224	37,031	37,031	24,687
Transaction costs	-	64,231	48,044	48,912	48,912	48,912	48,912	48,912	48,912	-
Carbon finance P/(L)	-	(64,231)	(48,044)	(48,912)	(31,331)	(19,568)	(12,688)	(11,881)	(11,881)	24,687
Carbon finance cumulative P/(L)	-	(64,231)	(112,275)	(161,187)	(192,518)	(212,086)	(224,774)	(236,655)	(248,536)	(223,849)
Total P/(L)	**(736)**	**740,232**	**(256,886)**	**(473,246)**	**(31,331)**	**(19,568)**	**(12,688)**	**(11,881)**	**(11,881)**	**(24,687)**
Total P/(L) cumulative	**(736)**	**739,496**	**482,610**	**9,364**	**(21,967)**	**(41,535)**	**(54,223)**	**(66,104)**	**(77,985)**	**(53,298)**

5.3.6. Conclusion

At present the project lacks defined project objectives and implementation costs beyond the existing grant period. The purpose of the financial analysis is to show the net revenue generation that would be made available as a result of access to carbon finance. Therefore a number of assumptions have been made that, the project does not generate revenue from the sales of the rice husk gasifier (RHG) units and the sources of revenues are from the sales of carbon credits and from the grants.

The study shows that project technology can generate emissions reductions at a level sufficient to cover the transaction costs of the obtaining certification, although at present this is limited to the voluntary carbon market. The analysis shows that the ER breakeven prices are relatively low compared to the market price for VGS but it is slightly higher than the market price for CDM. The analysis also shows the minimum size for a project to breakeven. At present market prices, under VGS, a viable project should consist of a yearly minimum average of 32 RHG, while CDM option requires a yearly minimum average of 154 to cover the cost of accessing carbon finance and the underlying project net loss. Therefore a project disseminating more than this number of units is to generate net revenue for the underlying project.

Using the existing project dissemination plan of 150 gasifiers over four years, two carbon finance routes, which are VGS and CDM, have been examined. There are pros and cons for each route to the market. Owing to the extremely low price per credit at the time of writing, there will be cumulative losses for CDM route throughout the seven year crediting period. However, there may be a price recovery or reduced regulatory risk though developing the project within the mandatory market. In this case the analysis may change but for the present time the CDM route cannot be recommended.

In contrast, the VGS route will generate net revenue from year 2018 onwards. Despite the fact that demand for voluntary credits are less assured, the relatively early cash inflows and higher ER price of render VGS to be the most attractive. Under the VGS route, over the course of a seven year crediting period the project would generate net revenue in the region of €461K. This revenue is what would be available to the project proponent following the cessation of grants in 2015.

5.4. Gap Analysis

The Feasibility Assessment shows that there are 3 possible scenarios for the development of a carbon project within the scope of the WtE project for the Rice Milling Sector in Cambodia. The table below shows what are the gaps to be fulfilled in each of the three scenario.

Table 48: Gap Analysis under three different scenarios

Gaps	Standalone CDM	Standalone VGS	CDM/Voluntary PoA
Prior Consideration form to be submitted to DNA and CDM EB	X	(X)[64]	-
Project Design	X	X	X
Additionality	X[65]	X[66]	X
Baseline study	completed	completed	completed
Project Proponent	X	X	X
Key funding sources of the project	X	X	X
ODA form	X	X	X
Pre-feasibility GS	-	X	-/X
Stakeholder Consultation	X	X	X
GS Passport	-	X	-/ X
PDD	X	X	-
PoA-DD	-	-	X
CPA-DD	-	-	X
General CPA-DD	-	-	X
Environmental Management Plan for mills with RHG units	X	X	X
Data Management Plan for mills with RHG units	X	X	X
GS Sustainability Matrix	-	X	-/X
CDM Sustainability Tool	X	-	X/-

[64] It is not a requirement but it is good practice to send it even if a VGS project is to be developed;
[65] To be updated once project design is finalized
[66] To be updated once project design is finalized

The main gaps stemming from Baseline Studies and Feasibility Studies results are as follow:

1. Submission of prior-consideration forms. The language of the EU Switch Asia proposal carbon finance is clear that carbon finance is only to be considered until feasibility stage. In this case there is documentary evidence that carbon finance is being considered, but further evidence is required to demonstrate an intention to develop a project. This can be achieved through the submission of Prior Consideration form to DNA and UNFCCC.

2. There is a lack of a clear project design and plan. The EU-Switch Asia proposal for the WtE Project does not include any carbon related activities other than the present feasibility assessment. Interviews with key SNV staff have confirmed that the decision to develop a carbon project is yet to be made. This has several implications:

    a. Lack of identifiable project proponent
    b. Lack of clear indications on the number of units to populate the project
    c. No clear start date for the carbon finance activities
    d. No clear indication of what the carbon finance will be used for

Therefore, a first step is to resolve the questions around the design of the carbon finance initiative. Central to this is also the need to resolve the questions of additionality. As the present grant funding has the objective of installing 150 gasifier explicitly without carbon finance. Therefore a clear decision needs to be made on what the purpose of carbon finance will be for. This could either cover improving affordability of gassifiers for millers or for the scale up of the project beyond the scale of the present proposal.

3. Completion of project documents. The baseline survey outlined in chapter 4 above was designed to comply with CDM sampling guidelines. However, additional project documentation is required. For the CDM this would consist of a Project Design Document. Under the Voluntary Gold Standard an additional document, the Gold Standard Passport, is required to be produced.

4. There is evident lack of funding source for the development of a potential carbon project within the WtE project for the Rice Milling sector in Cambodia. Interviews with key SNV staff have confirmed that funding sources are to be identified in a second phase based on the financial viability of the project with carbon finance. The financial analysis shows the level of funding required to cover the carbon finance transaction costs are in the region of €45K per year.

5. Baseline Study results highlights that there is evident lack of data management within mills facilities. Results show that more than 70% of the millers do not record data on energy consumption and milling activity. In case a carbon project is to be developed a clear data management plan needs to be put into place and appropriate capacity building provided to participating millers. Monitoring requirements from AMS.I.B methodology requires project proponent to monitor the following parameters:

    - Recording annually the number of systems operating (evidence of continuing operation, such as on-going rental/lease payments could be a substitute); and

    - Estimating the annual hours of operation for the equipment that uses the mechanical energy produced, if necessary using sampling methods. Annual hours of operation can be estimated from total output (tonnes of grain milled) and output per hour if an accurate value of output per hour is available.

- In the case of applications involving mechanical and electrical energy, the electrical energy generation should be metered.
- For projects where only biomass or biomass and fossil fuel are used the amount of biomass and fossil fuel input shall be monitored.
- If fossil fuel is used the energy produced metered should be adjusted to deduct production from fossil fuels using the specific fuel consumption and the quantity of fossil fuel consumed.
- If more than one type of biomass fuel is consumed each shall be monitored separately.
- The amount of energy produced using biomass fuels calculated as per paragraphs above shall be compared with the amount of energy calculated using specific fuel consumption and amount of each type of biomass fuel used. The lower of the two values should be used to calculate emission reductions. [67]

6. Baseline Study results show that mills are not recording any data on health and safety related issues. The millers have never been confronted by an overheated reactor. If any problem should happen, only three mills have procedures for fire prevention and fire fighting (gas and water extinguishers). No procedure for the employees, related to their work in contact with the gasifier and waste, has been reported. A comprehensive health and safety plan needs to be put into place in each mill part of the carbon project in compliance with GS sustainability matrix and CDM sustainability tool. These should be a requirement of inclusion within any carbon finance project.
7. Baseline Study results show that that only 40% of the mills employ women. In addition, women work approximately as many hours and days as men, but get paid almost two times less. Gold Standard requires a no-discrimination policy in terms of gender, race, and religion. Such a policy should be a requirement of inclusion within any carbon finance project.
8. Despite official laws on the regulation of waste water arisings, there is little evidence that there is any implementation or enforcement of environmental pollution legislation. This is a problem due to the local environmental pollution that results from operation of the gasifiers. There was a lack of awareness of the environmental pollution issues arising from operation of the gasifiers and the immediate local environment tended to be treated as a 'dumping ground' for liquid and sludge waste arisings.
9. One example of a waste water treatment system (the only one currently installed as a gasifiation unit in Cambodia) was observed and measurement demonstrates the effectiveness of the system. However, it was only treating c. 15% of the waste water arisings and, as a consequence; there was no evidence of a reduction in environmental pollution in the local environment compared to the other sites. A system treating 100% of the waste water would be effective, though the sludge arising would still need to be disposed of as a special waste since they are likely to contain high concentrations of organic pollutants.
10. The EIA only considered the environmental pollution in the settling pond, discharge streams and local disposal ponds. It is possible that pollutants could be conveyed into the underlying water table and into the surrounding land, especially during the rainy season. More extensive

[67] AMS.I.B CDM Methodology, [Online] Available at http://cdm.unfccc.int/methodologies/DB/5TDWYSV5EYM4332XSOUT4EV8XHT03G

surveying, including during the rainy season, could be undertaken to examine the potential dispersal of pollutants into the environment.

11. An EIA of a RHG that uses a dry gas clean-up system is crucial in obtaining the evidence base to justify the claim that such an approach has few environmental impacts than the wet gas scrubber that is currently used.

12. Specialised equipment could be used to measure the fugitive gas emissions (e.g. CO, CO_2, CH_4, H_2) from the reactor and from the pipe joins, in order to assess whether the existing technologies and operations are posing a health and safety risks to workers.

5.5. Road Map

A full Gantt chart is available on the attached excel file: **Supporting Document I - Gantt Charts for Validation and Verification of a standalone carbon projects.**

5.6. Conclusion

Nexus analysed different carbon standard approaches for the development of a rice husk carbon project in the Kingdom of Cambodia. The analysis was carried out in the compliant as well as in the voluntary market:

- VGS standalone project
- CDM standalone project
- Voluntary/CDM Programme of Activities

The Feasibility Assessment shows a number of strengths and weaknesses for the project. The project would be eligible as either a CDM or VGS standalone project using the CDM AMS I.B methodology ''*Mechanical energy for the user with or without electrical energy"*.

Whilst the project is eligible at a technology level, the principal issues occur at the project level, specifically the lack of a defined project for carbon finance. This is most evident in establishing the additionality of the project. Whilst there is clearly a case for additionality for a project disseminating gasifiers, this would need to be additional to the commitments under the existing grant proposals. Carbon finance would be required to either assist the project scale up or provide additional financial support for millers.

Aside from the issues of project design the technology has potential to generate significant quantities of emissions reductions. Preliminary Emission Reductions calculations indicate an average of 28,872.66 tCO_2/yr under the CDM scenario and an average of 30,348.17 tCO_2/yr under the VGS scenario. At this stage, calculated ERs represent only an estimation due to the lack of coherent project design and dissemination plan.

The Financial Analysis shows that project technology can generate emissions reductions at a level sufficient to cover the transaction costs of obtaining certification, although at present this is limited to the voluntary carbon market. The analysis shows that the ER breakeven prices to cover transaction costs are relatively low compared to the market price for VGS but it is slightly higher than the market price for CDM. The analysis also shows the minimum size for a Voluntary Gold Standard project to breakeven should consist of a yearly average minimum of 32 Rice-husk gasification units. In order to generate surplus revenue a VGS project would need to consist of more than 32 units. Owing to the current low price of credits, the CDM option requires a yearly average minimum of 154 Rice-husk gasification units to cover the cost of accessing carbon finance. In order to generate surplus revenue a CDM project would need to consist of more than 154 units. The financial analysis shows that a project of 150 digesters disseminated over 4 years could generate net revenue of around €440K under the VGS.

However, this conclusion should be treated with caution as the availability of grant funding to cover the initial dissemination raises additionality concerns. The decision to proceed with a carbon finance project would either require

- A project redesign such that carbon finance is used to make gasifier more affordable
- Scale up beyond 150 gasifiers such that the existing grant period is a pilot phase and carbon finance is used to cover the scale up of the initiative.

The lack of specific project design and organization willing to act as the project proponent, may mean that it is more suitable as a Program of Activities (PoA). A follow up by Nexus is examining the benefits of developing a rice-husk PoA compared with a stand-alone project under the Voluntary Gold Standard.

The table below presents a summary of key next steps, resolution methods, entity in charge of filling the gaps as well as a suggesting how the steps should be prioritized.

Table 49: Summary of next steps

Next steps			
Issue	**Resolution method**	**Entity in charge**	**Priority**
Assess the best approach	Feasibility Assessment to be updated based on new project design and based on detailed PoA Feasibility Assessment;	Carbon Specialist	High
Go-no go decision	SNV to convene a Board meeting to decide whether to go ahead with the development of the carbon project;	SNV and Carbon Specialist	High
Project Design	Organization to be chosen as project proponent and clear project design to be put into place;	SNV	High
Prior Consideration	Project proponent to prepare letter and send it to Cambodian DNA and EB;	Carbon Specialist	High
Identify Funding Stream	Project proponent to identify main funding stream to cover upfront project costs;	Project Proponent	Medium
Update Financial Analysis	Once the funding stream has been identified update financial analysis and cash flow;	Carbon Specialist	Medium
ODA Declaration	Once the funding stream has been identified submit the ODA form;	Project Participant and Carbon Specialist	Low

Update Baseline and Project Emission calculations	Baseline and Project Emissions to be updated based on new project design and identified funding stream;	Carbon Specialist	**Medium High**
Update the ER calculations estimates	ERs to be updated based on new project design and identified funding stream;	Carbon Specialist	**Medium High**
Additionality	Once the project design has been put in place and the project proponent has decided what to use carbon finance for, the additionality of the project should be reassessed.	Carbon Specialist	**Medium High**
GS Pre-feasibility Assessment	If the chosen standard if GS, pre-feasibility assessment to be developed;	Carbon Specialist	**Medium**
(CDM/VGS) Stakeholder Consultation	Project proponent to carry out a stakeholder consultation;	Project Proponent	**Medium**
LoA - DNA in Cambodia	Project Proponent to sign the Letter of Agreement with DNA in Cambodia;	Project Proponent	**Medium**
Update the ER calculations estimates	ERs to be updated based on new project design and identified funding stream;	Carbon Specialist	**Medium High**
PDD/ PoA PDD-CPA DD	If the carbon project is to be developed project design document needs to be prepared and sent to a third party auditor;	Carbon Specialist	**Low**
Management Plan: Environmental/ Health and Safety	Project proponent with support from carbon specialist and in cooperation with millers to develop a management plan in accordance with CDM/VGS rules (e.g. GS sustainability matrix, CDM sustainability tool);	Project proponent, Carbon Specialist, Millers	**Medium High**
Management Plan: Data Recording	Project proponent with support from carbon specialist and in cooperation with millers to develop a management plan in accordance with monitoring requirements of CDM AMS.I.B methodology.	Project proponent, Carbon Specialist, Millers	**Medium High**

6. Results: Environmental Impact Assessment

This section presents results from the Environmental Impact Assessment. The results are shown in the set of tables (Tables 51 – 57) below. The Environmental Impact Assessment focuses on waste water (figures 19, Annex 7), sludge (figure 17) and rice husk char (figure 16). In addition, because it was found out that tars (figure 18) from the gas filters are sometimes disposed of into the local environment, two filter tar samples were analysed.

The levels of potential contaminants are indicated in the Tables along with the maximum permissible limits (MPLs) for drinking water, water discharge standards (SDWPC) (two different standards) and for sediments (relevant for the sludges). A colour coding system is used to indicate where the sample concentration is higher than the appropriate MPL, hence where there is a case of environmental pollution which requires attention. For **water samples**, where a red colour is used this indicates that the concentration of the element or molecule, or value of the environmental parameter, is greater than the MPL for discharge to public water area and to sewers (SDWPC). A red colour therefore indicates environmental pollution. Where an amber colour is used, this indicates that the concentration of the element or molecule, or value of the environmental parameter, is greater than the MPL for discharge to protected public water areas, but lower than the MPL for discharge to public water area and to sewers (SDWPC). An amber colour therefore indicates a possible to likely case of environmental pollution.

For several organic molecules, there is no MPL in Cambodia (except for drinking water for a few species such as benzene) and for these we have used the MPL provided by a well know reference data base for MPLs in sediments – the Screening Quick Reference Tables of the National Oceanographic and Atmospheric Administration (NOAA) in the USA – the so-called Screening Quick Reference Tables (SQUIRTs).[68] SQUIRTs provides MPLs for both acute and chronic MPL, i.e. a one-off incident versus a continued introduction of the chemical species into the water body. A red colour is used where the concentration in the sample exceeds that of the acute level in SQUIRTs, indicative of a pollution problem. An amber colour is used where the concentration in the sample exceeds that of the chronic but not of the acute MPL in SQUIRTs, indicative of a potential to likely pollution problem. The drinking water standards (CDWQS) are shown in the tables for illustrative purposes, but are not used in establishing the MPLs since there was no evidence that any of the water bodies were used for extracting drinking water supplies.

For **sludges**, we have used MPLs for freshwater sediments. Since no standards for pollutants in sediments were identified in Cambodia, SQUIRTs has been drawn upon to provide a range of potential MPLs. For inorganics the ARCS values have been chosen wherever possible (developed by the US Environmental Protection Agency, report reference 905-R96-008). While for organics, the Dutch standards are presented – both intervention MPL and target MPL. A red colour indicates that the chemical concentration in the sample exceeds the ARCS value (inorganics) or the intervention value (organics). An amber colour indicates that the chemical concentration in the sample exceeds the target level for organics in sediments but is lower than the intervention value for organics. As above, a red colour indicates pollution and amber possible to likely pollution. For the two tar samples, we have used the same sediment values for organic contaminants as for sludges.

[68] Buchman, M. F. (2008), NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle, WA, Office of Response and Restoration Division, 34 pages.

Three sets of measurements were undertaken. Firstly, *in situ* field measurements of four environmental variables (temperature, pH, Electrical Conductivity and Dissolved Oxygen). Secondly, biological and chemical oxygen demand (BOD/COD) were measured. Thirdly, a suite of chemical analytical tests were undertaken in the laboratory to measure a wide range of elements and molecules.

6.1. Field Measurements of pH, Electrical Conductivity and Dissolved Oxygen

The field measurements of pH indicated that in the large majority of cases the pH is neutral to somewhat alkaline, but well within the acceptable range. Electrical conductivity (EC) measures the presence of ions that carry a negative charge (e.g. chloride, nitrate, sulphate, and phosphate) as well as positively charged metal ions. The field measurements of EC in the waste water settling ponds and in the final disposal ponds are very high, indicating high levels of water pollution (Figure 27). Distilled water has a conductivity in the range of 0.5 to 3 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm. In the light of the above information, we have selected a MPL of 1,500 µmhos/cm.

Many of the settling and waste water disposal ponds exhibited EC of 2000 to 7000 µmhos/cm. Where we were able to measure baseline levels in clean ponds near to the gasifiers, we found much lower EC values. At site 4, for example, the clean pond (figure 41) baseline had an EC that was 30 times lower than the settling pond and 60 times lower than the disposal pond. At site 9, a local 'clean' pond had an EC that was some six times lower than the final disposal pond. Note, however, that this 'clean' pond at site 9 showed signs of eutrophication (figure 46), hence was unlikely to be a non-polluted environmental baseline.

The EC for settling pond water was above the MPL selected for sites 1, 2, 3, 4 and 5 and also for the discharge stream water at sites 5, 6, 7 and 8 and for the disposal pond at sites 4 and 9. However, the EC was below the MPL for the disposal pond at sites 1 and 8. The two clean ponds (sites 4 and 9) had a much lower EC than the waste water disposal ponds and much lower than the MPL.

Dissolved oxygen (DO) measures the quantity of oxygen in the water column. A lower DO indicates a greater demand for oxygen within the water body. High demand for oxygen in water bodies tends to indicate an over-abundance of algae and / or cyanobacteria. Such over-abundance is usually associated with the introduction of too many nutrients such as nitrates and phosphates into the water column, as N and P are typically limiting factors for algal growth in water. Hence, high levels of DO typically indicate a clean water system while low levels indicate presence of pollutants. The DO measurements in the clean ponds tended to be in the order of 4 to 7 mg per litre, whereas the settling tanks and disposal ponds exhibited very low DO levels, around 0.15 to 0.4 mg per litre, indicative of high levels of pollution (Figure 27). The DO levels were too low compared to the guidance for sites 1 (settling pond and disposal pond), site 2 (settling pond water), site 3 (settling pond water), site 4 (disposal pond water), site 8 (disposal pond water) and site 9 (waste water stream and disposal pond).

6.2. Laboratory Measurements of BOD, COD, Nitrates, Phosphates and Chlorides

Biochemical oxygen demand (BOD) is: "the quantity of dissolved oxygen in water (mg/l) consumed (under test conditions) by microbial degradation of organic material during a time period (5 days). It is one of the standard tests used to characterize effluent quality and measures organic pollution in surface waters".[69] The BOD5 refers to the amount of oxygen in milligrams consumed per litre of the sample over a five-day incubation period at 20°C. Chemical oxygen demand (COD) is another way of measuring the quantity of organic compounds in water, but is less specific than BOD because it measures all organic matter than can be chemically oxidized, not just the biologically active organic matter. It is also measured in milligrams of oxygen consumed per litre of sample. High BOD and COD indicate the presence of organic pollutants.

BOD and COD were measured on 'fresh samples' in the laboratory. The large majority of cases showed very high BOD and COD levels (Figures 28 and 29) – an order of magnitude greater than the regulatory maximum permissible limits (MPLs) in Cambodia in many instances; and two orders of magnitude greater than the level in clean ponds in the vicinity of the gasifiers. For example at site 4, the BOD5 in the clean adjacent pond was 3 mg per litre, while it was 320 mg/l in the waste water disposal pond. The regulatory limit is 80 mg/l for a public water body and sewer. The equivalent COD values were 37 mg/l (clean pond), 2840 mg/l (disposal pond) with the regulatory limit of 100 mg/l (Figure 28 and 29).

BOD and COD levels were beyond the discharge standard level at site 4 – both settling pond and disposal pond - but not at the waste water treatment facility. This suggests that the waste water treatment plant is effective for the portion of waste water that it treats (15% of total) but that the remaining 85% that is not treated results in organic pollution in the disposal pond (compare figures 38 with 40). BOD and COD are exceeded (relative to the regulatory threshold) in the waste water discharge stream at site 7 and also in the waste water stream and disposal pond at site 9 (as also in the adjacent pond suffering from eutrophication, but not receiving any waste water from the gasifier). All the waste water samples tested for BOD and COD exceeded the MPL with the exception of the treated waste water at site 4. The clean pond water at site 4 had a very low BOD and COD.

Measurements of nitrates, phosphates and chlorides in water samples confirm moderately high levels that are sometimes above the regulatory maximum permissible limits (MPLs).

The total suspended solids (TSS) and the total dissolved solids (TDS) are higher than the MPL in the case of most waste water samples tested (Figure 31). Grease and oil levels are also higher than the MPL in some cases, but not in others. For example, at site 5, grease and oil in the sludge sample from the waste water settling pond are far greater than the MPL. Grease and oil levels are also too high in the stream discharge waste water at site 5.

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[69] Morris, P. & Therivel, R. (eds.) (2001), Methods of Environmental Impact Assessment, 2nd Edition, Spon Press, London, page 470

6.3. Laboratory Measurements of Metals in Water and Sludge Samples

Metal levels in waste water are higher than the MPL in a number of samples tested. The metal this happened for most frequently was manganese (e.g. at 2, 4, 7, 8) possibly arising from the metal of the gasifier. Other metals which sometimes appear at levels above the MPL are copper, lead, iron and chromium. Note that if total metals in the sample are measured (not just dissolved portion) then other elements begin to look potentially too high, including arsenic and mercury as well as copper, lead, iron and zinc (Table 55). In the majority of cases metal pollution does not appear to be a major problem in waste water samples arising from the gasifiers. The sludge samples tested tend to demonstrate levels of several metals that are beyond the MPL, e.g. for zinc (1, 4, 6), chromium (4, 5, 8), nickel (4, 6), copper (5, 6), iron (5, 8), lead (5, 8, 6) and manganese (5, 7 ,8, 6).

6.4. Laboratory Measurements of Organic Compounds in Water, Sludge and Tar Samples

The most noticeable red blocks in Tables 51 to 57 are those referring to the organic molecules. There are two main groups considered – BETX (benzene, ethylbenzene, meta + para xylene, orthoxylene and toluene), and PAHs (polycyclic aromatic hydrocarbons). Both groups contain molecules that can be toxic and, in some cases, carcinogenic. Hence, the fact that concentrations of these chemicals are frequently way above the MPL is a cause for concern.

At site 1, there are very high levels of BETX in the disposal and settling pond sludge. There are very high levels of PAHs in the disposal pond sludge and even more so in the tar sample. At site 3, BETX levels in settling pond water are high, as also are PAH levels in the settling pond sludge, though much less than at site 1. PAH levels in the tar sample from site 3 are very high and similar to those in the tar from site 1.

At site 4, BETX levels are reasonably high for settling pond water, settling pond sludge and disposal pond water, though less than at site 1. PAH levels are high for settling pond water sludge at site 4. Levels of PAHs are also beyond the MPL in the sludge from the waste water treatment system at site 4, similar to the levels in the disposal pond sludge, but 5% to 30% of the levels in the settling pond sludge. Hence, the waste water treatment system is removing 95 to 70% of the PAHs compared to the settling tank, but the levels remaining are still far above the MPL. For example, the total PAHs for settling tank sludge are between 10,000 and 68,000 mg/kg, while for the sludge from the waste water cleaning tank the concentration is c. 3,300 mg/kg. However, the MPL is only about 40 mg/kg. The PAH levels in the disposal pond sludge at site 4 are slightly lower than those in the waste water treatment facility sludge, presumably due to microbial decomposition; however, the total is c. 2,600 mg/kg, a lot higher than the MPL.

At sites 5 and 6, waste water from the settling ponds and water discharge to stream exceed the MPLs for several of the BETX species. The sludge from stream discharge at site 5 exceeds the MPL for benzene and is in the 'amber' area for other BETX species. This sludge sample exceeds the MPL for a number of PAHs though concentrations are a lot less than at other sites such as 1 and 4.

Settling tank sludge at site 7 has 'amber' levels of BETX and exceeds MPLs for a number of PAHs, with other concentrations in the 'amber' zone. Again PAH levels at this site are lower than at sites 1 and 4. Disposal pond sludge at site 9 is moderately high in BETX and exceeds the MPLs for several PAHs, while other PAHs remain within the 'amber zone'.

6.5. Laboratory Measurements of Inorganic and Organic Elements and Compounds in Rice Husk Char (RHC)

Inorganic elements in rice husk char (RHC) are reported in Table 58 (last column). The levels are all moderate and a source of micro-nutrients if the RHC are incorporated into the soil. The levels are lower than the MPLs provided in guidance on the use of biochar in soil provided by the International Biochar Initiative[70], the European Biochar Certificate (EBC)[71] and the Biochar Risk Assessment Framework (BRAF), though mercury, lead and manganese concentrations might be close to, or slightly higher in some cases, than the MPL. For this reason, high applications to soil (say beyond 30 tonnes per hectare (3kg per m^2)) are not recommended.

PAH levels from five different RHC samples tested are reported in Table 58. Four of the samples have total PAHs ranging from 14 to 35 mg/kg, which is well within the safe level if incorporated into soil at a few percentage of soil mass. However, the PAH levels are in some cases higher than those recommended by the IBI (6 to 20 mg/kg), the EBC (4 – 12 mg/kg) and BRAF (<20 mg/kg). One sample has a considerably higher PAH level of 104 mg/kg. If this RHC is incorporated into soil at a few percent by mass, it will still be at a low level in absolute terms.

6.6. Quantitative Risk Assessment

In order to evaluate whether RHC or sludges recovered from gasifier settling ponds might constitute a risk to animal or human health, the Quantitative Risk Assessment developed by the Biochar Risk Assessment Framework (BRAF) was used (personal communication, Rodrigo Ibarrola, University of Edinburgh, February 2013).

Scenario One: It was assumed that RHC recovered from the bottom of gasifier settling ponds would be spread onto the surface of grazing land, with some direct ingestion by animals. At very high application rates (50 t/ha), this RHC poses a risk from exposure to high concentrations of arsenic and manganese. (In this particular RHC, the manganese concentration is high (270 mg/kg) possibly due to preferential binding of the metal by the rice husk from the waste water stream). The PAHs would not be a health or environmental risk, although naphthalene concentrations are moderately high. At lower application rates of this RHC (e.g. 2-5 t/ha) there is no risk. Hence, the recommendation would be that the RHC can be used but, to be on the safe side, at lower application rates.

Scenario Two: Sludge from the gasifier settling ponds is spread onto the surface of grazing land, with some direct ingestion by animals. This sludge has similar problems to the RHC recovered from the bottom of the gasifier ponds, with high concentrations of arsenic and manganese. The concentration of manganese is extremely high (2688 mg/kg); lead is also a problem as it is above the MPL (44 mg/kg). Even at a very low application rate, manganese remains a problem. The concentrations of PAHs is very high for naphthalene (1214 mg/kg). The recommendation would be not to use this material for spreading onto soil.

6.6.1. Effect of Gasifier Design

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[70] IBI (2012), Standardized Product Definition and Product Testing Guidelines for Biochar that is Used in Soil, IBI, Washington DC.

[71] EBC (2012), Guidelines for Biochar Production, European BiocharCertificate, Delinat Institute, Switzerland

Figure 25 plots data on the total BETX and PAHs from different sites and reactors. It can be seen that gasifiers (1) and (4) have far higher levels of BETX and PAHs than all the other gasifiers. Removing the highest concentrations allows a comparison to be made of the lower concentrations of BETX and PAHs from the other gasifiers, in Figure 26. Figures 25 and 26 illustrate that no clear relationship between the reactor manufacturer and the level of pollutant can be established. (1) and (4) are both Ankur reactors, but so are (6) and (9), which have much lower levels of BETX and PAHs. (3) is Seng Kuch design and (5) and (7) are Chanrorn design, all of which seem to have lower levels of BETX and PAHs than (1) and (4).

It is more likely that the levels of BETX and PAHs depend upon the operational history and on-going operation of the gasifier – e.g. the length of time it has been operating, the load factor, local environmental conditions such as dispersal of pollutants from disposal ponds, etc. Site (4) is operating 24 hours a day for 7 days a week so creating a larger amount of waste water and sludge than other gasifiers. Gasifiers that are not running as frequently produce less waste and there is more time for degradation and oxidation of organic chemicals.

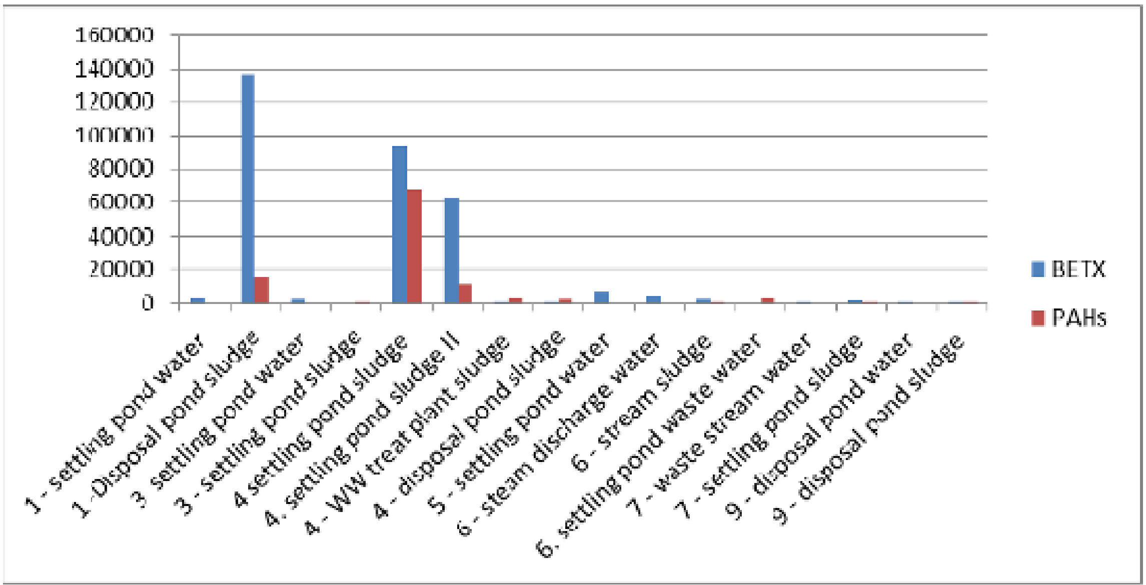

Figure 25: BETX and PAH concentrations in waste water and sludge

Figure 25 shows results from samples taken at sites 1, 3, 4, 5, 6, 7 and 9. (Units mg/l or mg/kg dry weight). The regulatory threshold for the PAHs is close to the 'x' axis at 40 mg/kg.

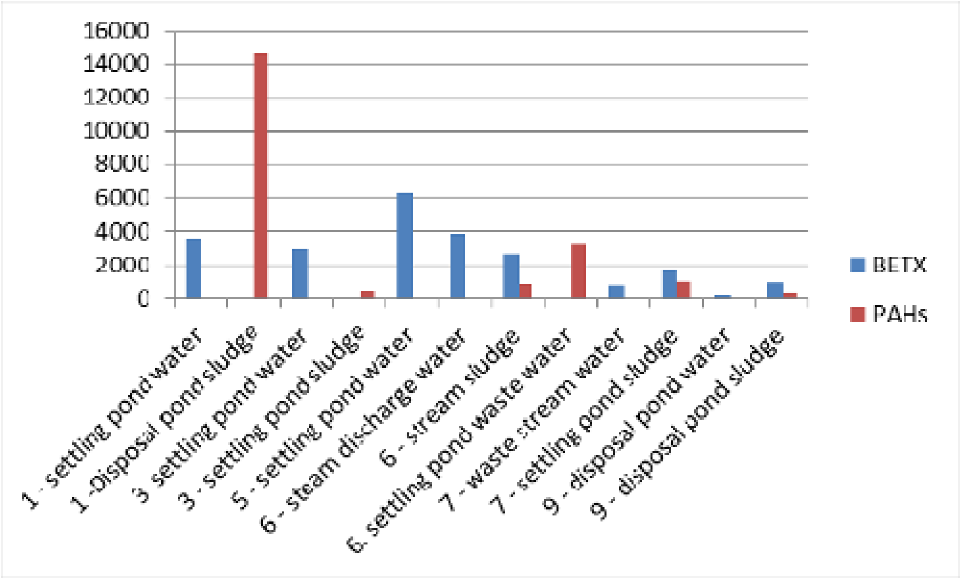

Figure 26: BETX and PAH concentrations in waste water and sludge

Figure 26 shows results from samples from sites 1, 3, 5, 6, 7 and 9 (removing the highest peaks at site 1 and 4). (Units mg/l or mg/kg dry weight). The regulatory threshold for the PAHs is close to the 'x' axis at 40 mg/kg.

Figure 26 plots data on Dissolved Oxygen (DO) and Electrical Conductivity (EC) from across all nine sites. Polluted water is indicated when the vertical red line (EC) is above the horizontal black line and when the vertical blue line (DO) is below the horizontal green line. Three examples of very clean water stand out (i.e. tall blue lines and short red lines) – the ponds at sites 4 and 9 which do not receive any of the contaminated black waste water and the treated waste water at site 4 (illuminating that the waste water treatment system is very effective in cleaning-up the water). Another pond free of gasifier waste water at site 9 was polluted in other ways and showed extensive algal bloom indicative of eutrophication.

The most polluted water bodies are those with a tall red line and a short blue line and the settling ponds at sites 1 and 2 are the best examples. Of course, the settling ponds are expected to contain large amounts of polluted water given that they receive the waste water from the gasifiers. As the waste water discharges from the settling ponds and enters local streams or ponds, however, the high pollution level endures. Dissolved oxygen levels are consistenly below the target level and the only exceptions are the stream discharge at site 7, the settling pond at site 4 (for unknown reasons) and the high level of DO in water that has been treated at site 4.

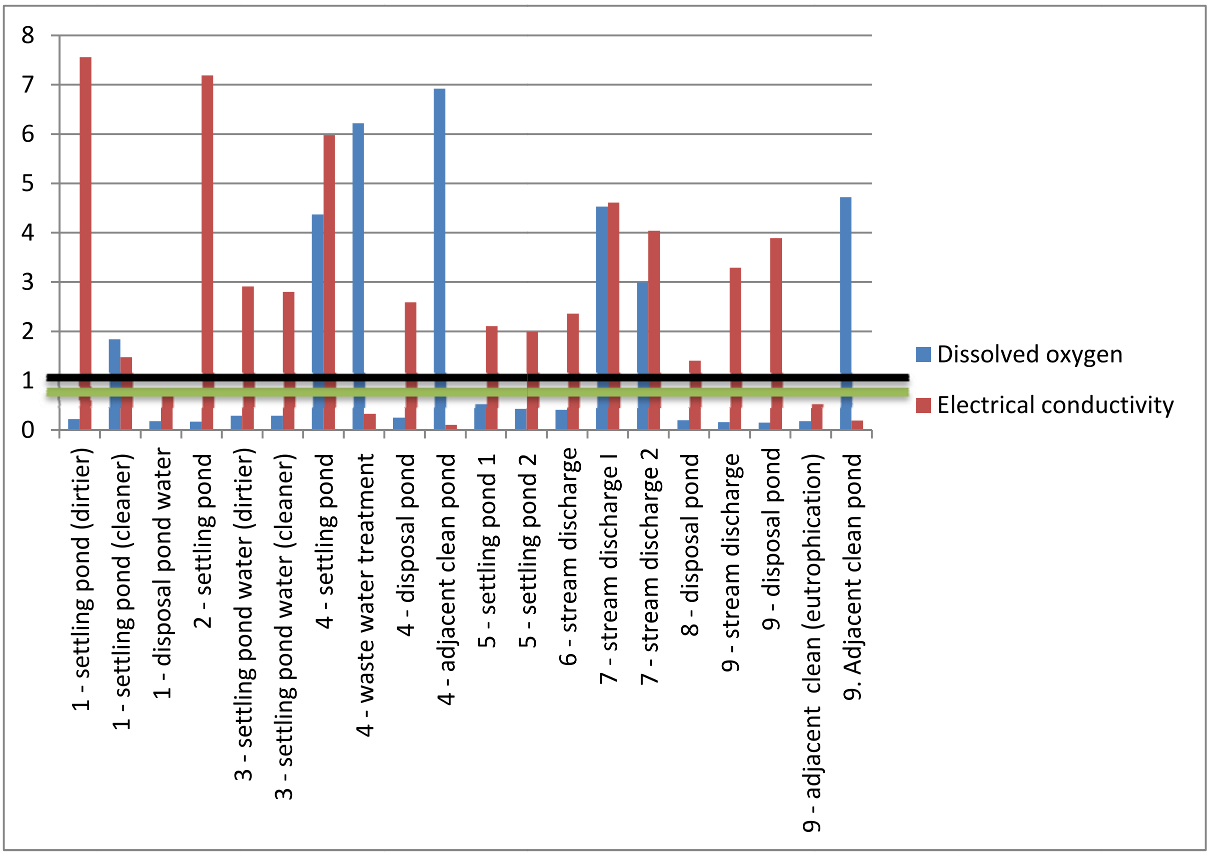

Figure 27: Dissolved Oxygen (DO) and Electrical Conductivity (EC)

The black horizontal line shows the threshold selected for EC across the 9 sites, clean water having a *lower* EC than this. The green horizontal line shows the threshold selected for DO, clean water having a *higher* DO level than this. (Units mg/l (DO) and millisiemens per cm (EC).

The EC measurements are above the threshold, indicating polluted waters, in most of the settling ponds, disposal ponds and stream discharges. There are just two instances where waste water bodies (disposal ponds) had EC levels below the threshold, at sites 1 and 8. Higher levels of EC tend to be associated with lower levels of DO, suggesting that pollution is both organic and inorganic. In some instances, the inorganic ions are high (high EC) but the organic pollution levels are lower (high DO) (e.g. at sites 4 and 7) suggesting that the two types of water pollution do not necessarily go hand-in-hand. It is clear from Figure 27, that there are no clear trends in relation to levels of pollution from different gasifier designs. It is more likely that the pollution burden is related to the individual history of each site – e.g. the load-factor of the gasifier (number of operational hours per year), long-term accumulation of waste water and capacity for waste water to be washed out, dispersed and decomposed, etc. For example, visual inspection of site 1 suggests that the disposal pond does not connect to an external stream from which waste could be gradually dispersed – hence the persistent organic pollutants may be building-up over time, though microbial degradation will also act to consume organic molecules in appropriate conditions.

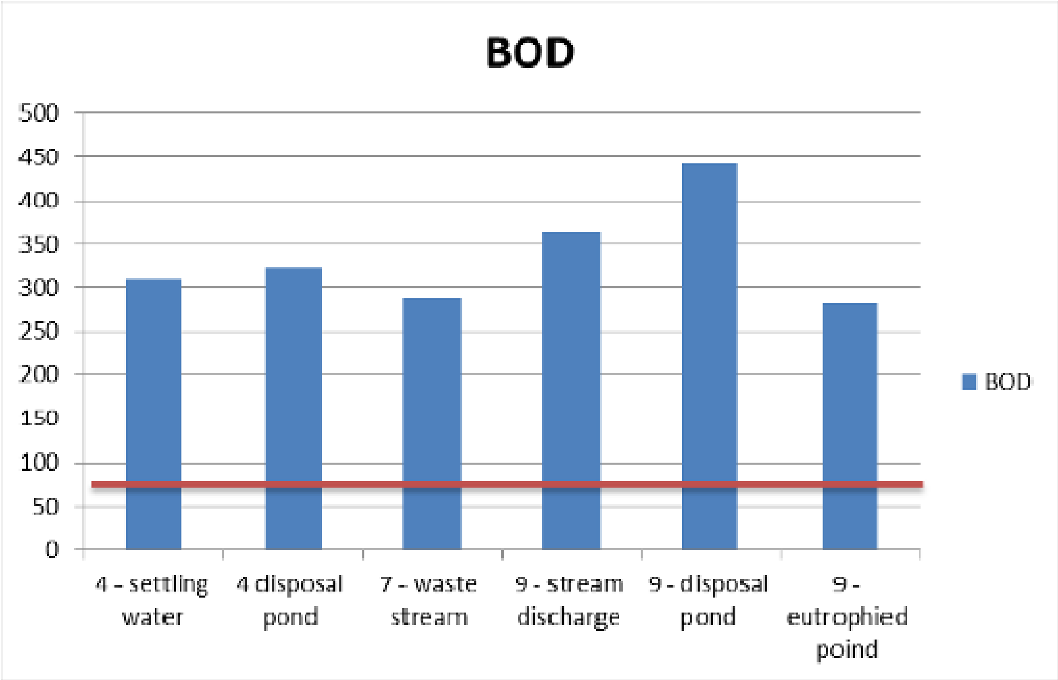

Figure 28: Biological oxygen demand (BOD) (Dissolved Oxygen in mg per litre)

The horizontal brown line in Figure 28 indicates the regulatory threshold, above which waste water contains too much pollution.

BOD measurements are plotted in Figure 28. It can be seen that the values are all much higher than the threshold and also that the levels do not vary by a large amount. Interestingly, the level of pollution is similar to that in an adjacent pond at site 9 which was suffering from eutrophication due to an unknown source of pollutants. Site 9 is one of the longest-operating gasifiers in Cambodia, hence the somewhat higher levels of BOD may reflect the accumulation of organic matter over time. COD levels are presented in Figure 29. With the exception of site 1, COD levels are reasonably similar. It is not known why COD levels at site 1 are so much higher than at the other sites sampled. Since it is not reflected by the BOD level, it suggests that there is organic material entering into the settling pond at the site which is not decomposable by microorganisms. The settling pond water from site 1 is also anomalously high in chloride ions (see Figure 30) and has a very high EC (Figure 27), providing further support to the suggestion that there is something anomalous about the operation of the gasifier compared to the other sites, or that an additional waste water stream is entering the settling pond.

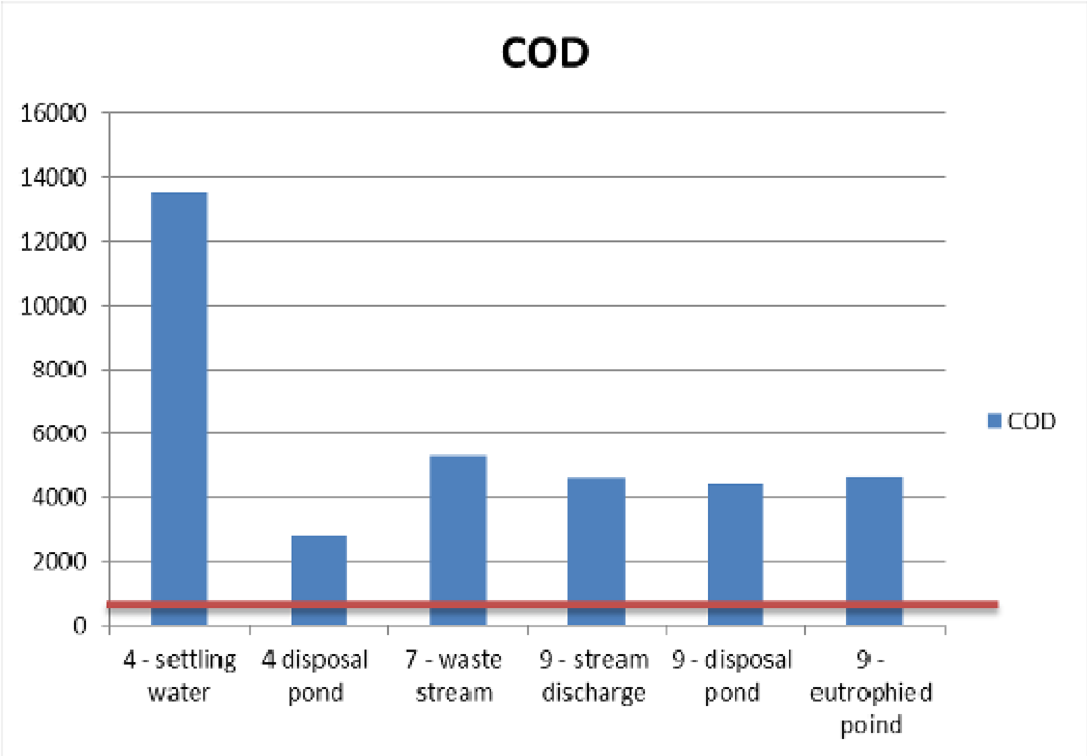

Figure 29: Chemical oxygen demand (BOD) (Dissolved Oxygen in mg per litre).

The horizontal brown line indicates the regulatory threshold, above which waste water contains too much pollution.

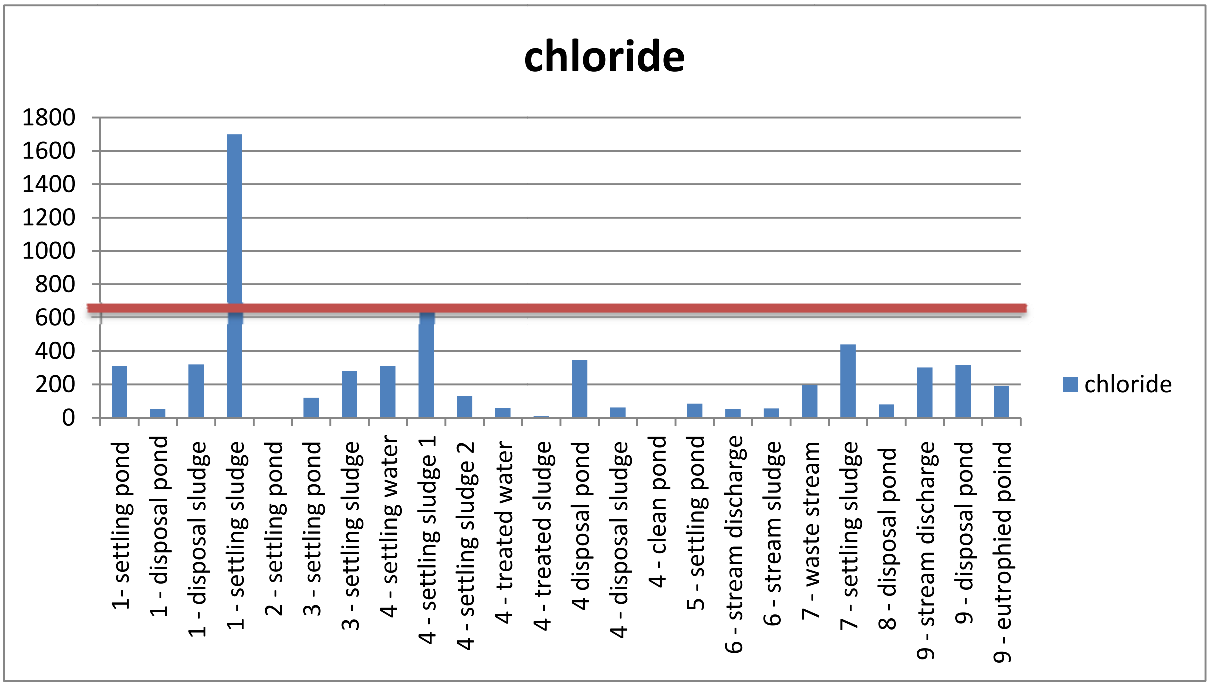

Figure 30: Concentrations of chloride in waste water and sludge samples. (Units: mg/l)

The brown horizontal line indicates the threshold, above which chloride concentration is regarded as being too high.

Figure 31 plots data on total suspended solids (TSS) and total dissolved solids (TDS). TSS levels are in all cases too high relative to the regulatory threshold (80 mg/l) and especially high at site 1. The TDS levels are high at sites 8 and 9, where they exceed the regulatory threshold (2000 mg/l). The longer number of years of operation of the gasifier at site 9 compared to the other sites may help to explain the accumulation of TDSs.

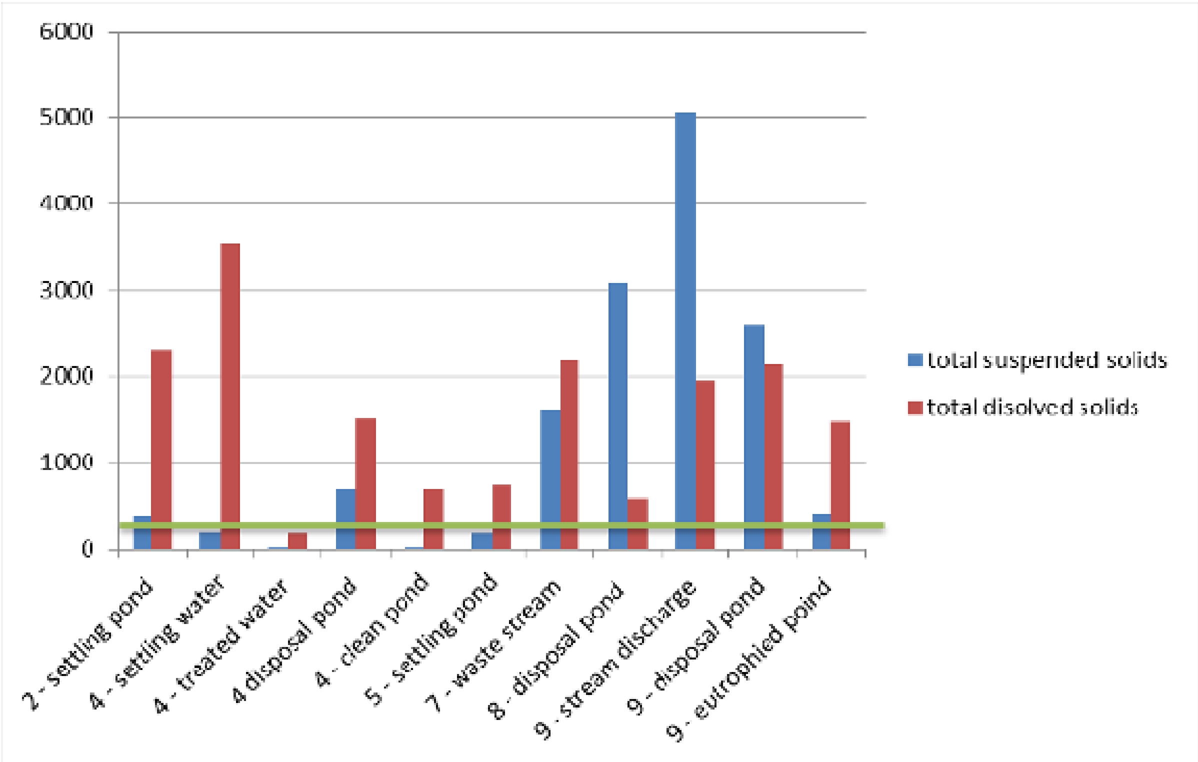

Figure 31: Concentration of total suspended and total dissolved solids (TSS, TDS)

The regulatory threshold beyond TSS is considered too high is shown by the horizontal green line, while the equivalent level for TDS is at 2000 mg/l. (mg per litre).

6.7. Summary of Results and Next Steps

In summary, the data that has been assembled indicates that the black waste water streams cause serious localized pollution of end disposal ponds and of streams into which the black water flows. Some of this pollution is persistent, as in accumulation of heavy metals in the water body, in particular manganese (and, to a lesser extent, copper, lead, iron, chromium and zinc), while zinc, chromium, magnesium, copper, nickel, lead and iron accumulate in some of the sediments tested. The high Electrical Conductivity measurements are indicative of the presence of negatively and positively charged ions and, where measured, moderate to high levels of nitrate, chloride and phosphate were discovered.

Of even more concern is the introduction of large amounts of organic molecules into the water bodies. The very high Biological and Chemical Oxygen Demand (where measured) indicates the high loading of ponds and streams with a complex mixture of organic compounds. This high loading and associated high BOD/COD is reflected by low measured DO levels and effectively kills-of other forms of life in ponds and streams such as fish, frogs, plants and macroinvetebrates (insects, spiders, crustaceans) which are unable to survive in such low oxygen water bodies.

Very high levels of single benzene-ring type molecules (benzene, ethylbenzene, ortho-, meta- and para- benzene and toluene) were discovered in all the waste water and sediment samples tested. Heavier molecular weight polycyclic aromatic hydrocarbon (PAHs) molecules (composed of two, three, four and five-benzene rings) were discovered at very high levels in most of the waste water and sediment samples. The one sample in which lower PAH levels were identified was sediment from the disposal pond at site 9, the longest running gasifier in Cambodia. It is possible that presence of BETX and PAHs over a time period of years have provided a strong selective pressure for microorganisms that are able to breakdown such molecules and use them as a source of carbon and energy, hence there is a higher turn-over of the organic contaminants. Laboratory incubation studies would be required to test this hypothesis. If demonstrated, such microbial cultures might be used to help breakdown of persistent organic pollutants at existing sites.

Whether the organic and inorganic pollution can disperse from the disposal ponds and marshy areas laterally or vertically through the water table is not known and was not tested for in this study. A more detailed hydrological analysis and survey would be required to determine whether this is a problem or not but there seems at least a possibility that dispersion could happen for more mobile pollutants.

The tars collected at the base of the syngas filters also contain very high levels of BETX and PAHs and need to be disposed of safely as a special waste. On the other hand, the rice husk char (RHC) is a clean material and typically contains acceptable levels of heavy metals and PAHs. However, in one case tested, the RHC had a somewhat higher concentration of PAHs and chemical analysis and a quantitative risk assessment is advised before such material is incorporated into agricultural soils. In terms of metal and organic contaminants, many RHC samples could be used at 20 or so tonne per hectare application levels without introducing any environmental or health and safety risks, provided that they have not been contaminated with settling pond sludge. There are agronomic and economic considerations which will determine suitable application levels of RHC on agricultural soils. Too much RHC in soil could end up removing soil N by sorption, reducing availability for plants, especially in low N systems.[72] Practically, farmers are unlikely to have the resources and time to apply large quantities of RHC on to their fields, as it will add to field operations.

Site 4 is the only gasifier in Cambodia which has a waste water treatment system. This system works well and the resulting water is very clean, with a high DO and low EC and no significant level of pollutants in the waste water. However, the sludge collected from the waste water treatment system still contains very high levels of PAHs. Unfortunately, furthermore, the waste water treatment system at site 4 only has the capacity to treat 15% of the waste water arisings from the gasifier. The other 85% remains untreated and flows into the disposal pond. The water quality in the final disposal pond is very poor and no better than that in other waste water disposal ponds. Clearly, the waste water treatment system would need to be scaled-up to treat all of the waste water.

[72] Asai, H., et al. (2009), 'Biochar amendment techniques for upland rice production in Northern Laos', *Field Crops Research* 111: 81-84

6.8. Environmental Management Plan

None of the sites visited had an Environmental Management Plan (EMP) in place. While an EMP is not required in Cambodian law at the present time, development of such would be a useful way for operators and owners to meet their obligations under the laws which do cover the operation of biomass gasifiers (discussed in Section 3) and carbon standards (Annex 8). This includes the likely requirement in the next few years for a more detailed Environmental Impact Assessment (EIA). The legal framework is largely already in place, but requires more detailed sub-decrees and guidance and, most importantly, enforcement by regulatory agencies. The key elements of an EMP for the RHGs can be articulated as below.

- Waste Water Management. Further development of gasifiers without appropriate waste water treatment systems that manage a large majority of the waste water arisings risks polluting the environment local to the facilities. The long-term effect of such pollution is unknown but could posit a long-term threat to human health and local ecosystems, reduce the ability to utilize land in the future for food production and could pollute human drinking water sources. The Ankur waste water system works well but, if it only treats 15% of the waste water (as at site 4), it does little to reduce environmental pollution to the local environment. Therefore, the waste water treatment system has to be large enough to cope with 100% of the waste water arisings. This might require the use of several waste water treatment systems 'in parallel', where additional units can be brought online as load factor increases.
- The sludge (sediment) from the bottom of the settling tanks, disposal ponds and discharge streams contains high levels of toxicants and should be managed as a special waste and disposed of appropriately. Drying settling pond sludge and its clean combustion, used as an ingredient in building materials or else disposal to a waste handling facility (e.g. a licensed landfill site), is strongly recommended. The sludge should not be disposed of in the local environment, nor should sludge be added to the piles of rice husk char, since this risks contaminating the otherwise clean RHC material.
- Likewise, the tars arising from the syngas filters contain high levels of organic toxicants and need to be carefully disposed of.
- The various sludges produced by the waste water treatment system will need to be handled as special wastes and disposed of appropriately, e.g. dried and used in building material, incinerated or land-filled, etc.
- Dry char discharge systems for the rice husk char are desirable as they reduce the waste water arisings. Dry char discharge is now being installed on new Ankur gasifier units and a number are already operating in Cambodia (e.g. site 4 and 8).
- Ankur Scientific Pvt. Ltd. (Vadodara, India) is developing a 'dry' gas clean-up system. This will remove the generation of black waste water arisings completely. It is strongly advised that future purchases of gasifiers invest in the dry gas clean-up system when available to avoid many of the environmental pollution problems discovered in this EIA. The wastes such as BETX, heavy metals and PAHs will still be generated, however, so appropriate disposal by gaseous combustion or safe disposal of the solid waste stream from the gas clean-up unit will still be essential.
- The Rice Husk Char (RHC) needs to be kept separate from the waste water streams to avoid sorption of metals or organic contaminants into the char, thereby introducing the possibility of adding toxicants to soil if RHC is added to land. At moderate applications levels (few tonnes per hectare to circa 20 tonnes per hectare), the RHC can have a beneficial effect upon soils and agricultural production by providing nutrients, increasing pH, retaining soil moisture and enhancing Cation Exchange Capacity in weathered local soils.

Table 50: Next Steps: Environmental Management Plan

Next steps			
Pollution Risk	**Proposed Mitigation Measures**	**Entity in charge**	**Priority**
Waste Water: field measurements show high level of water pollution indicated by high level of EC, low DO level, very high BOD and COD as well as TSS and TDS. Laboratory measurements show that metals in waste water are higher than MPL, especially manganese, lead, iron, chromium, copper, arsenic, zinc, zinc. Of most concern are very high concentrations of BETX and PAH compounds, some of which are toxic and carcinogenic and which are present at far higher concentrations than MPLs. The long-term effect of such pollution is unknown but could posit a long-term threat to human health and local ecosystems.	Dry char discharge systems are developed which reduce the need for water clearance and reduce potential contamination of the rice husk char. Waste water treatment systems are available that effectively treat the waste water and produce a clean water effluent. To be effective, waste water treatment needs to be applied to 100% of the waste water arisings. Avoiding the arisings of waste water in the first place is the best option and Ankur is developing a dry gas clean-up system. This is the preferred long-term option though if other solid wastes are produced from a gas clean-up system they will need to be disposed of carefully.	Operator Government regulator Ankur Scientific Pvt. Ltd. (Vadodara) has developed the dry char discharge , waste water treatment system and the dry gas clean-up system. Similar designs can be developed by other companies.	HIGH
Sludge: laboratory measurements highlight presence of several metals beyond MPL: zinc, chromium, nickel, copper, iron, lead and manganese. Of more concern are the very high levels of BETX and PAH compounds, some of which are toxic and carcinogenic and which are present at far higher concentrations than MPLs.	As above. Where waste water treatment systems are installed, sludges are still generated and contain a lot of PAHs, a lot higher than the MPL. These sludges need to be disposed of carefully, e.g. dried and safely incinerated, used in building materials or landfilled in licensed sites.	Operator Government regulator	HIGH
Rice Husk Char: Generally a clean material though on occasion can have some what high levels of manganese, lead and arsenic and a number of PAHs.	Prior to use as a soil amendment, the RHC should be tested chemically as prescribed by IBI, EBC or BRAF. If levels of metals or PAHs are higher than some MPLs, a Quantitative Risk Assessment for agronomic application is desirable. Moreover rice husk char should be out into the waste disposal ponds. The RHC will bind the PAHs and prevent their movement out of the sediment. The RHC should remove the PAHs from the water column.	Users of RHC using IBI, EBC and BRAF guidance	MEDIUM

Tars from gas filters: Tars contain BETX and PAH compounds, some of which are toxic and carcinogenic and which are present at far higher concentrations than MPLs.	Tars need to be treated as a special waste and disposed of carefully, e.g. safely incinerated, used in road construction materials or landfilled in licensed sites.	Operator Government regulator	**HIGH**

Table 51: Environmental Parameters for Gasifier Site 1[73]

Parameter	Units	Drinking water (CDWQS)	Discharge standards - SDWPC		Screening levels for sediments - USEPA	1 Settling pond waste water (dirtier)	1 Disposal pond water	1 Disposal pond water sludge	1 Disposal pond sludge water	1 Settling pond sludge	1 Filter unit tar waste
Code						1KTSTW	1KTDPW	1KTDPS	1KTDPSW	1KTSTS	1KTFT
Laboratory						NWSS	NWSS	NWSS	NWSS	NWSS	
			Protected public water area	Public water area and sewer	ARCS (EPA) for sediments						
Arsenic	mg/l (mg/kg)	0.05	0.1	1	10.79	0.010	0.030	<0.40	0.011	<0.40	
BOD	DO mg/l		30	80							
Boron	mg/l (mg/kg)		1	5		<0.40	<0.40	20	<0.40	19	
Cadmium	mg/l (mg/kg)	0.003	0.1	0.5	0.58	<0.00020	0.00021	<0.20	0.00036	<0.20	
Chloride	mg/l	250	500	700		310	52	400	320	1700	
Chromium	mg/l (mg/kg)	0.05	0.05	0.5	36.29	0.00081	0.018	5.3	0.0028	<2.0	
Cobalt	mg/l (mg/kg)					<0.00070	0.045	0.21	<0.00070	<0.20	
COD	DO mg/l		50	100							
Copper	mg/l (mg/kg)	1	0.2	1	28.012	0.017	0.037	2.3	0.019	<2.0	
Dissolved oxygen	DO mg/l		> 2	> 1		0.22 / 1.84[d]	0.18				

[73] **Red colour** indicates that the concentration of the element or molecule, or value of the environmental parameter, is greater than the MPL for discharge to public water area and to sewers (SDWPC). A red colour therefore indicates environmental pollution. **Amber colour** indicates that the concentration of the element or molecule, or value of the environmental parameter, is greater than the MPL for discharge to protected public water areas, but lower than the MPL for discharge to public water area and to sewers (SDWPC). An amber colour therefore indicates a possible to likely case of environmental pollution.

Electrical conductivity	ms/cm	1.5[e]	-	-		7.56 /1.476[d]	0.818					
Fluoride	mg/l	1.5	-	-								
Grease & oil	mg/l		5	15								
Iron	mg/l	0.3	1	20	18.84%							
Lead	mg/l	0.01	0.1	1	37.00	<0.0020	0.094	<2.0	<0.0020	<2.0		
Manganese	mg/l	0.1	1	5	630.00							
Mercury	mg/l (mg/kg)	0.001	0.002	0.05					<0.060	<0.060		
Molybdenum	mg/l (mg/kg)		0.1	1.0		<0.00030	<0.00030	<0.30	<0.00030	<0.30		
Nickel	mg/l (mg/kg)	0.02	0.2	1.0	19.51	0.00083	0.033	3.0	0.0060	<2.0		
Nitrate	mg/l as NO_3^-	50	10	20								
pH	pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0		7.14 / 7.7[d]	7.35					
Phosphate	mg/l as PO_4^{3-}	-	3	6								
Selenium	mg/l (mg/kg)	0.01	0.05	0.5		0.00073	0.00091	<0.20	0.0010	<0.20		
Sodium	mg/l (mg/kg)	200	-	-		76	33	580	78	980		
Temperature	^0C					34	26					
Total suspended solids	mg/l		50	80								
Total dissolved solids	mg/l	800	1000	2000								
Total solids	%							18.73				
Zinc	mg/l (mg/kg)	3	1.0	3.0	98.00	0.097	0.63	110	0.45	12		
Organics		Dutch sediment intervention levels	Dutch sediment target levels	Freshwater Acute (NOAA)	Freshwater Chronic (NOAA)							
Benzene	µg/l	1000	10	2300	46	2900	<10	100,000	4100	240,000		
Ethylbenzene	µg/l	50,000	30	130	14	35	<10	19,000	76	39,000		
Meta + para xylene	µg/l	18,000	110	32	1.8	53	<10	33,000	87	68,000		
Orthoxylene	µg/l	9,300	89		350	33	<10	17,000	52	34,000		
Toluene	µg/l	47,000	10	120	9.8	570	<10	67000	760	160,000		
Acenaphthene	mg/kg	0.29[a]						370			480	
Acenaphthylene	mg/kg	0.16[a]						1900			2200	

Anthracene	mg/kg	1.60	0.039					1100			1000
Benzo(a)anthracene	mg/kg	2.50	0.025					480			1200
Benzo(b)fluoranthene	mg/kg	1.80[b]						98			160
Benzo(k)fluoranthene	mg/kg	38.00	0.38					53			180
Benzo(a)pyrene	mg/kg	7.0	0.052					49			100
Benzo(g,h,i)perylene	mg/kg	33.00	0.57					35			110
Chrysene	mg/kg	35.00	8.10					320			520
Dibenzo(a,h)anthracene	mg/kg	0.1[a]						<10			<100
Fluoranthene	mg/kg	260	1					860			760
Fluorene	mg/kg	0.30 [a]						1200			
Indeno(1,2,3-cd)pyrene	mg/kg	1.90	0.031					20			<100
Naphthalene	mg/kg	17.00	0.12					3300			6400
Phenanthrene	mg/kg	3.1	3.3					4300			4100
Pyrene	mg/kg	0.49[c]						680			580
∑PAHs (USEPA 16)	mg/kg	40	1					14638			18,890

(a) UET value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(b) AET value, in NOAA, Screening Quick Reference Table for Organics in Marine Sediment
(c) LEL value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(d) Second values are from settling pond waste water (cleaner)
(e) Value of 1,500 µmhos/cm used based on literature

Table 52: Environmental Parameters for Gasifier Sites 2 and 3

Parameter	Units	Drinking water (CDWQS)	Discharge standards - SDWPC		Screening levels for sediments - USEPA	2. Settling pond waste water	3. Settling pond waste water (dirtier)	3. Settling pond waste water (cleaner)	3. Settling pond sludge	3. Filter unit tar waste
Code						2CSCPW	3PPSTW		3PPSTS	3PPFT
Laboratory						ILCC	NWSS		NWSS	
			Protected public water area	Public water area and sewer	ARCS (EPA) for sediments					
Arsenic	mg/l (mg/kg)	0.05	0.1	1	10.79		0.015		0.53	
BOD	DO mg/l		30	80						
Boron	mg/l (mg/kg)		1	5			<0.40		24	
Cadmium	mg/l (mg/kg)	0.003	0.1	0.5	0.58		0.00053		<0.20	
Chloride	mg/l	250	500	700			120		280	
Chromium	mg/l (mg/kg)	0.05	0.05	0.5	36.29	0.00577	0.0014		<2.0	
Cobalt	mg/l (mg/kg)			50a			0.0012		<0.20	
COD	DO mg/l		50	100						
Copper	mg/l (mg/kg)	1	0.2	1	28.012	0.072	0.016		2.7	
Dissolved oxygen	DO mg/l		> 2	> 1		0.17	0.29	0.29		
Electrical conductivity	ms/cm	1.5[d]	-	-		7.19	2.91	2.8		
Fluoride	mg/l	1.5	-	-						
Grease & oil	mg/l		5	15		0.72				
Iron	mg/l	0.3	1	20	18.84%	0.55				

Lead	mg/l	0.01	0.1	1	37.00		<0.0020		<2.0	
Manganese	mg/l	0.1	1	5	630.00	1.117				
Mercury	mg/l (mg/kg)	0.001	0.002	0.05	0.20[a]				<0.060	
Molybdenum	mg/l (mg/kg)		0.1	1.0			<0.00030		<0.30	
Nickel	mg/l (mg/kg)	0.02	0.2	1.0	19.51		0.0092		<2.0	
Nitrate	mg/l as NO_3^-	50	10	20						
pH	pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0		7.48	5.17	5.11		
Phosphate	mg/l as PO_4^{3-}	-	3	6						
Selenium	mg/l (mg/kg)	0.01	0.05	0.5	1[b]		0.00040		<0.20	
Sodium	mg/l (mg/kg)	200	-	-			28		220	
Temperature	^{0}C					43.8	33.5	32.6		
Total suspended solids	mg/l		50	80		373				
Total dissolved solids	mg/l	800	1000	2000		2310				
Total solids	%								23.38	
Zinc	mg/l (mg/kg)	3	1.0	3.0	98.00		0.13		15	
Organics		Dutch sediment intervention levels	Dutch sediment target levels	Freshwater Acute (NOAA)	Freshwater Chronic (NOAA)					
Benzene	µg/kg	1000	10	2300	46		2000			
Ethylbenzene	µg/kg	50,000	30	130	14		44			
Meta + para xylene	µg/kg	18,000	110	32	1.8		77			
Orthoxylene	µg/kg	9,300	89		350		49			
Toluene	µg/kg	47,000	10	120	9.8		760			
Acenaphthene	mg/kg	0.29[a]							<10	460

Acenaphthylene	mg/kg	0.16[a]							17	1100
Anthracene	mg/kg	1.60	0.039						23	640
Benzo(a)anthracene	mg/kg	2.50	0.025						170	1200
Benzo(b)fluoranthene	mg/kg	1.80[b]							11	150
Benzo(k)fluoranthene	mg/kg	38.00	0.38						16	180
Benzo(a)pyrene	mg/kg	7.0	0.052						<10	110
Benzo(g,h,i)perylene	mg/kg	33.00	0.57						<10	150
Chrysene	mg/kg	35.00	8.10						37	610
Dibenzo(a,h)anthracene	mg/kg	0.1[a]							<10	<100
Fluorene	mg/kg	0.30[a]							16	910
Fluoranthene	mg/kg	260	1						14	460
Indeno(1,2,3-cd)pyrene	mg/kg	1.90	0.031						<10	<100
Naphthalene	mg/kg	17.00	0.12						51	2700
Phenanthrene	mg/kg	3.1	3.3							2700
Pyrene	mg/kg	0.49[c]								450
∑PAHs (USEPA 16)	mg/kg	40	1						445	11,720

(a): UET value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(b): AET value, in NOAA, Screening Quick Reference Table for Organics in Marine Sediment
(c): LEL value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(d): Value of 1,500 µmhos/cm used based on literature

Table 53: Environmental Parameters for Gasifier Site 4

Parameter	Units	Drinking water (CDWQS)	Discharge standards - SDWPC		Screening levels for sediments - USEPA	4. Settling pond waste water	4. Settling pond waste water sludge	4. Settling pond sludge	4. Waste water treatment system output	Waste water treatment system sludge	4. Disposal pond water	4.Disposal pond sludge	4. Clean Pond Water
Code						4REESTW	4REESTW	4REESTS	4REEWWCUS	4REEWWCUSS	4REEDPW	4REEDPS	4REECPW
Laboratory						RDIC / NWSS	NWSS	NWSS	RDIC & NWSS	NWSS	RDIC & NWSS	NWSS	RDIC & NWSS
			Protected public water area	Public water area and sewer	ARCS (EPA) for sediments								
Arsenic	mg/l (mg/kg)	0.05	0.1	1	10.79	0 / 0.0037	<0.40	<0.40	0 / 0.0013	1.5	0.0047	3.8	0 / 0.0014
BOD5	DO mg/l		30	80		310.38			2.3		321.75		3.1
Boron	mg/l (mg/kg)		1	5		< 0.40	40	21	/ <0.40	5.1	<0.40	3.9	< 0.40
Cadmium	mg/l (mg/kg)	0.003	0.1	0.5	0.58	/ <0.00020	0.32	<0.20	/ 0.00020	<0.21	<0.00020	<0.20	/ <0.00020
Chloride	mg/l	250	500	700		309.13 / 270	640	130	110 / 9.5	8.5	193.86 / 380	62	6.38 / 5.9
Chromium	mg/l (mg/kg)	0.05	0.05	0.5	36.29	/ 0.0019	3.6		/ 0.00038	24	/ 0.0030	40	/ 0.00084
Cobalt	mg/l (mg/kg)	50				/ 0.00070	0.28		/ <0.00070	3.7	/ 0.0014	2.5	/ <0.00070
COD	DO mg/l		50	100		13550			10		2840		37
Copper	mg/l	1	0.2	1	28.012	/ 0.020	13		/ 0.017	110	/ 0.014	13	/ 0.0087

	(mg/kg)												
Dissolved oxygen	DO mg/l		> 2	> 1		4.37			6.22		0.25		6.92
Electrical conductivity	ms/cm	1.5[d]	-	-		5.98			0.327		2.59		0.1046
Fluoride	mg/l	1.5	-	-		< MDL			0.44		<MDL		<MDL
Grease & oil	mg/l		5	15									
Iron	mg/l	0.3	1	20	18.84%								
Lead	mg/l	0.01	0.1	1	37.00	/ 0.0035	<2.0	<2.0	/ 0.0020	20	/ 0.0020	8.3	/ 0.0020
Manganese	mg/l	0.1	1	5	630.00	0.74			0.03		2.13		0.05
Mercury	mg/l (mg/kg)	0.001	0.002	0.05	0.20	0.00043	<0.060	<0.60		0.082		0.087	
Molybdenum	mg/l (mg/kg)		0.1	1.0		<0.00030	<0. 30	0.33	/ 0.00030	0.51	/ 0.00030	0.45	/ 0.00030
Nickel	mg/l (mg/kg)	0.02	0.2	1.0	19.51	0.0013	2.2	4.3	0.0082	31	/ 0.0021	4.0	/ 0.0011
Nitrate	mg/l as NO_3^-	50	10	20		15.18			74.43		9.35		3.16
pH	pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0		7.63			8.25		7.62		6.83
Phosphate	mg/l as PO_4^{3-}	-	3	6		18.97			1.59		12.91		<MDL
Selenium	mg/l (mg/kg)	0.01	0.05	0.5		0.00064	0.62	<0.20	/ 0.00017	<0.02	/ 0.00076	0.30	/ 0.00012
Sodium	mg/l (mg/kg)	200	-	-		2.29 / 11	280	93	9.77 / 32	130	2.24 / 11	<60	1.57 / 5.7
Temperature	°C					27.4			33.1		28.6		27.3
Total suspended solids	mg/l		50	80		200			2.5		700		2

Total dissolved solids	mg/l	800	1000	2000		3550			181		1509		697
Solids	%						9.54	15.47		33.55		43.64	
Zinc	mg/l (mg/kg)	3	1.0	3.0	98.00	0.027	58	52	/ 0.032	1200	/ 0.035	20	<0.0060
		Dutch fresh water sediment intervention levels	Dutch fresh water sediment, target levels	Fresh water Acute (NOAA)	Fresh water Chronic (NOAA)								
Benzene	µg/l	1000	10	2300	46	2800	42,000	5500	<10	200	130	540	<10
Ethylbenzene	µg/l	50,000	30	130	14	28	5900	2200	<10	21	<10	130	<10
Meta + para xylene	µg/l	18,000	110	32	1.8	50	13,000	4500	<10	<10	<10	260	<10
Orthoxylene	µg/l	9,300	89		350	27	6400	2500	<10	<10	<10	140	<10
Toluene	µg/l	47,000	10	120	9.8	610	26,000	4800	<10	60	38	330	<10
Acenaphthene	mg/kg	0.29[a]					1000	200		57		45	
Acenaphthylene	mg/kg	0.16[a]					7900	1000		320		220	
Anthracene	mg/kg	1.60	0.039				6600	1300		340		280	
Benzo(a)anthracene	mg/kg	2.50	0.025				2100	530		200		170	
Benzo(b)fluoranthene	mg/kg	1.80[b]					500	84		36		25	
Benzo(k)fluoranthene	mg/kg	38.00	0.38				240	48		25		15	
Benzo(a)pyre	mg/kg	7.0	0.052				320	48		20		13	

ne													
Benzo(g,h,i)perylene	mg/kg	33.00	0.57				100	23		13		<10	
Chrysene	mg/kg	35.00	8.10				2100	360		140		110	
Dibenzo(a,h) anthracene	mg/kg	0.1[a]					<10	<10		<10		<10	
Fluoranthene	mg/kg	260	1				6000	830		270		220	
Fluorene	mg/kg	0.30[a]					5900	720		220		180	
Indeno(1,2,3-cd)pyrene	mg/kg	1.90	0.031				94	<10		<10		<10	
Naphthalene	mg/kg	17.00	0.12				4200	51		310		180	
Phenanthrene	mg/kg	3.1	3.3				26,000	3900		1100		960	
Pyrene	mg/kg	0.49[c]					5400	710		250		200	
∑PAHs (USEPA 16)	mg/kg	40	1				68,297	10,863		3268		2618	

(a): UET value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(b): AET value, in NOAA, Screening Quick Reference Table for Organics in Marine Sediment
(c): LEL value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(d): Value of 1,500 µmhos/cm used based on literature

Table 54: Environmental Parameters for Gasifier Sites 5 and 6

Parameter	Units	Drinking water (CDWQS)	Discharge standards – SDWPC		Screening levels for sediments - USEPA	5. sludge from waste water settling pond	5. Stream discharge waste water	5. Settling pond waste water A	5. Settling pond waste water B	6. Stream discharge waste water	6. Sludge from stream discharge
			Protected public water area	Public water area and sewer							
Code						5CBCPS	5CBSDW	5CBSTW		6ESDSW	6ESDSS
Laboratory					ARCS (EPA) for sediments	ILCC	ILCC	NWSS		NWSS	NWSS
Arsenic	mg/l (mg/kg)	0.05	0.1	1	10.79			0.0050		0.0012	<0.40
BOD	DO mg/l		30	80							
Boron	mg/l (mg/kg)		1	5				<0.40			9.3
Cadmium	mg/l (mg/kg)	0.003	0.1	0.5	0.58			<0.00020		<0.00020	<0.20
Chloride	mg/l	250	500	700				85		53	56
Chromium	mg/l (mg/kg)	0.05	0.05	0.5	36.29	0.216	0.00177	0.0013		0.00097	<2.0
Cobalt	mg/l (mg/kg)				50			0.0051		0.0023	<0.20
COD	DO mg/l		50	100							
Copper	mg/l (mg/kg)	1	0.2	1	28.012	1.094	0.017	0.013		0.011	<2.0

Dissolved oxygen	DO mg/l		> 2	> 1				0.5	0.43	0.41	
Electrical conductivity	ms/cm	1.5[d]	-	-				2.107	1.992	2.36	
Fluoride	mg/l	1.5	-	-							
Grease & oil	mg/l		5	15		600	31.79				
Iron	mg/l	0.3	1	20	18.84%	141.728	4.6				
Lead	mg/l	0.01	0.1	1	37.00	0.1029	0.053475	<0.0020		<0.0020	<2.0
Manganese	mg/l	0.1	1	5	630.00	91.064	2.149				
Mercury	mg/l (mg/kg)	0.001	0.002	0.05							<0.060
Molybdenum	mg/l (mg/kg)		0.1	1.0				<0.00030		0.0012	<0.30
Nickel	mg/l (mg/kg)	0.02	0.2	1.0	19.51			0.0040		0.0038	<2.0
Nitrate	mg/l as NO_3^-	50	10	20							
pH	pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0				6.13	6.45	7.45	
Phosphate	mg/l as PO_4^{3-}	-	3	6							
Selenium	mg/l (mg/kg)	0.01	0.05	0.5				0.00028		0.00071	<0.20
Sodium	mg/l (mg/kg)	200	-	-				17		45	120
Temperature	°C							38.9	37.4	33.1	
Total suspended solids / total solids	mg/l		50	80			175				
Total dissolved solids	mg/l	800	1000	2000			738				

Total solids	%										29.95
Zinc	mg/l (mg/kg)	3	1.0	3.0	98.00			0.034		0.12	17
Organics		Dutch fresh water sediment intervention levels	Dutch fresh water sediment, target levels	Fresh water Acute (NOAA)	Fresh water Chronic (NOAA)						
Benzene	µg/l	1000	10	2300	46			4600		3100	2100
Ethylbenzene	µg/l	50,000	30	130	14			79		41	<10
Meta + para xylene	µg/l	18,000	110	32	1.8			150		48	140
Orthoxylene	µg/l	9,300	89		350			80		25	<10
Toluene	µg/l	47,000	10	120	9.8			1400		610	390
Acenaphthene	mg/kg	0.29[a]									14
Acenaphthylene	mg/kg	0.16[a]									65
Anthracene	mg/kg	1.60	0.039								48
Benzo(a)anthracene	mg/kg	2.50	0.025								150
Benzo(b)fluoranthene	mg/kg	1.80[b]									<10
Benzo(k)fluoranthene	mg/kg	38.00	0.38								<10
Benzo(a)pyrene	mg/kg	7.0	0.052								<10
Benzo(g,h,i)perylene	mg/kg	33.00	0.57								<10
Chrysene	mg/kg	35.00	8.10								33

Dibenzo(a,h) anthracene	mg/kg	0.1[a]									<10
Fluoranthen e	mg/kg	260	1								30
Fluorene	mg/kg	0.30[a]									33
Indeno(1,2,3 -cd)pyrene	mg/kg	1.90	0.031								<10
Naphthalene	mg/kg	17.00	0.12								220
Phenanthren e	mg/kg	3.1	3.3								160
Pyrene	mg/kg	0.49[c]									24
∑PAHs (USEPA 16)	mg/kg	40	1								777

(a): UET value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(b): AET value, in NOAA, Screening Quick Reference Table for Organics in Marine Sediment
(c): LEL value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(d): Value of 1,500 µmhos/cm used based on literature

Table 55: Environmental Parameters for Gasifier Sites 7 and 8

Parameter	Units	Drinking water (CDWQS)	Discharge standards - SDWPC		Screening levels for sediments - USEPA	7. Waste stream water	7. Waste Stream water	7. Sludge from settling tank	8. Disposal pond water	8. Disposal pond water	8. Disposal pond sludge
			Protected public water area	Public water area and sewer							
Code						7TPWSW	7TPWSW	7TPWSS	8OCDPW	8OCDPW	8OCDPS
Laboratory					ARCS (EPA) for sediments	ILCC	RDIC / NWSS	NWSS	ILCC	NWSS	ILCC
Arsenic	mg/l (mg/kg)	0.05	0.1	1	10.79		0 / 0.0095	0.53		0.012	
BOD5	DO mg/l		30	80			287.63				
Boron	mg/l (mg/kg)		1	5			/ <0.04	6.4		<0.04	
Cadmium	mg/l (mg/kg)	0.003	0.1	0.5	0.58		/ 0.00023	<0.20		0.00025	
Chloride	mg/l	250	500	700			230.33 / 160	440		80	
Chromium	mg/l (mg/kg)	0.05	0.05	0.5	36.29	0.022192	/ 0.0034	8.7	0.064733	0.0065	5.100343
Cobalt	mg/l (mg/kg)				50[a]		/ 0.0019	1.5		0.015	
COD	DO mg/l		50	100			5300				
Copper	mg/l (mg/kg)	1	0.2	1	28.012	1.207	/ 0.022	4.4	0.090	0.063	2.245

Dissolved oxygen	DO mg/l		> 2	> 1		4.53	2.99		0.2		
Electrical conductivity	ms/cm	1.5[d]	-	-		4.61	4.04		1.404		
Fluoride	mg/l	1.5	-	-			<MDL				
Grease & oil	mg/l		5	15		1.06			15.12		500
Iron	mg/l	0.3	1	20	18.84%	12.393			30.820		2392.836
Lead	mg/l	0.01	0.1	1	37.00	0.050668	< 0.0020	<2.0	0.020837	0.024	1.114
Manganese	mg/l	0.1	1	5	630.00	2.848	2.17		3.868		53.790
Mercury	mg/l (mg/kg)	0.001	0.002	0.05			0	<0.06			
Molybdenum	mg/l (mg/kg)		0.1	1.0			<0.00030	<0.30		0.00076	
Nickel	mg/l (mg/kg)	0.02	0.2	1.0	19.51		0.0059	3.7		0.013	
Nitrate	mg/l as NO_3^-	50	10	20			8.58				
pH	pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0		7.65	7.68		6.73		
Phosphate	mg/l as PO_4^{3-}	-	3	6			51.43				
Selenium	mg/l (mg/kg)	0.01	0.05	0.5			0.00037	<0.20		0.00044	
Sodium	mg/l (mg/kg)	200	-	-			11.0 / 45			20	
Temperature	^oC					39.5	25.6		27.8		
Total suspended solids / total solids	mg/l		50	80		601	1600		3083		
Total dissolved solids	mg/l	800	1000	2000		1606	2179		592		
Total solids	%							29.61			
Zinc	mg/l (mg/kg)	3	1.0	3.0	98.00		0.10	81		0.57	
Organics		Dutch	Dutch	Freshwater	Freshwater						

		sediment intervetion levels	sediment target levels	Acute (NOAA)	Chronic (NOAA)						
Benzene	µg/l	1000	10	2300	46		650	830		<10	
Ethylbenzene	µg/l	50,000	30	130	14		<10	120		<10	
Meta + para xylene	µg/l	18,000	110	32	1.8		<10	190		<10	
Orthoxylene	µg/l	9,300	89		350		<10	140		<10	
Toluene	µg/l	47,000	10	120	9.8		76	390		<10	
Acenaphthene	mg/kg	0.29[a]						24			
Acenaphthylene	mg/kg	0.16[a]						68			
Anthracene	mg/kg	1.60	0.039					69			
Benzo(a)anthracene	mg/kg	2.50	0.025					160			
Benzo(b)fluoranthene	mg/kg	1.80[b]						13			
Benzo(k)fluoranthene	mg/kg	38.00	0.38					14			
Benzo(a)pyrene	mg/kg	7.0	0.052					<10			
Benzo(g,h,i)perylene	mg/kg	33.00	0.57					<10			
Chrysene	mg/kg	35.00	8.10					54			
Dibenzo(a,h)anthracene	mg/kg	0.1[a]						<10			
Fluoranthene	mg/kg	260	1					55			
Fluorene	mg/kg	0.30[a]						50			
Indeno(1,2,3-[cd])pyrene	mg/kg	1.90	0.031					<10			
Naphthalene	mg/kg	17.00	0.12					120			
Phenanthrene	mg/kg	3.1	3.3					280			
Pyrene	mg/kg	0.49[c]						53			
∑PAHs (USEPA 16)	mg/kg	40	1					960			

(a): UET value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(b): AET value, in NOAA, Screening Quick Reference Table for Organics in Marine Sediment
(c): LEL value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(d): Value of 1,500 µmhos/cm used based on literature

Table 56: Environmental Parameters for Gasifier Site 9

Parameter	Units	Drinking water (CDWQS)	Discharge standards - SDWPC		Sediment contaminant levels	9. waste water stream	9. waste water disposal pond	9. waste water disposal pond	9. waste water disposal pond (sediment)	9. pond with no gasifier waste water (but eutrophication)	9. pond next to mill (no evidence of gasifier waste water inflow)
			Protected public water area	Public water area and sewer							
Code						9SHWSW	9SHWPW	9SHWPW	9SHWPW	9SHCPW	
Laboratory					ARCS (EPA) for sediments	RDIC	RDIC / NWSS	NWSS			
Arsenic	mg/l (mg/kg)	0.05	0.1	1	10.79	0	0	0.0094	3.5	0	
BOD5	DO mg/l		30	80		364	442			284.38	
Boron	mg/l (mg/kg)		1	5				<0.40	5.4		
Cadmium	mg/l (mg/kg)	0.003	0.1	0.5	0.58			0.00048	<0.20		
Chloride	mg/l	250	500	700		300.91	316.34	85	150	190.15	
Chromium	mg/l (mg/kg)	0.05	0.05	0.5	36.29			0.079	33		
Cobalt	mg/l (mg/kg)				50[a]			0.036	8.4		
COD	DO mg/l		50	100		4620	4450			4670	
Copper	mg/l (mg/kg)	1	0.2	1	28.012			0.020	19		
Dissolved oxygen	DO mg/l		> 2	> 1		0.16	0.15			0.18	4.72

Electrical conductivity	ms/cm	1.5[d]	-	-		3.29	3.89			0.514	0.1906
Fluoride	mg/l	1.5	-	-		3.42	<MDL			<MDL	
Grease & oil	mg/l		5	15							
Iron	mg/l	0.3	1	20	18.84%						
Lead	mg/l	0.01	0.1	1	37.00			0.023	5.7		
Manganese	mg/l	0.1	1	5	630.00	1.92	2.1			2.38	
Mercury	mg/l (mg/kg)	0.001	0.002	0.05					<0.060		
Molybdenum	mg/l (mg/kg)		0.1	1.0				<0.00030	0.49		
Nickel	mg/l (mg/kg)	0.02	0.2	1.0	19.51			0.067	15		
Nitrate	mg/l as NO_3^-	50	10	20		9.38	9.23				
pH	pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0		7.34	7.33			7.49	8.57
Phosphate	mg/l as PO_4^{3-}	-	3	6		2.79	21.43				
Selenium	mg/l (mg/kg)	0.01	0.05	0.5				0.0016	<0.20		
Sodium	mg/l (mg/kg)	200	-	-		5.07	9.63	13	180		
Temperature	^oC					25.9	29.5			27.6	33
Total suspended solids / total solids	mg/l		50	80		5060	2595			400	
Total dissolved solids	mg/l	800	1000	2000		1941	2139			1471	
Total solid	%								22.22		
Zinc	mg/l	3	1.0	3.0	98.00			0.94	90		

	(mg/kg)										
Organics		Dutch sediment intervetion levels	Dutch sediment target levels	Freshwater Acute (NOAA)	Freshwater Chronic (NOAA)						
Benzene	µg/l	1000	10	2300	46			140	370		
Ethylbenzene	µg/l	50,000	30	130	14			<10	95		
Meta + para xylene	µg/l	18,000	110	32	1.8			<10	90		
Orthoxylene	µg/l	9,300	89		350			<10	57		
Toluene	µg/l	47,000	10	120	9.8			60	300		
Acenaphthene	mg/kg	0.29[a]							<10		
Acenaphthylene	mg/kg	0.16[a]							<10		
Anthracene	mg/kg	1.60	0.039						15		
Benzo(a)anthracene	mg/kg	2.50	0.025						190		
Benzo(b)fluoranthene	mg/kg	1.80[b]							<10		
Benzo(k)fluoranthene	mg/kg	38.00	0.38						<10		
Benzo(a)pyrene	mg/kg	7.0	0.052						<10		
Benzo(g,h,i)perylene	mg/kg	33.00	0.57						<10		
Chrysene	mg/kg	35.00	8.10						38		
Dibenzo(a,h)anthracene	mg/kg	0.1[a]							<10		
Fluoranthene	mg/kg	260	1						12		

Fluorene	mg/kg	0.30[a]							<10		
Indeno(1,2,3-cd)pyrene	mg/kg	1.90	0.031						<10		
Naphthalene	mg/kg	17.00	0.12						18		
Phenanthrene	mg/kg	3.1	3.3						56		
Pyrene	mg/kg	0.49[c]							13		
∑PAHs (USEPA 16)	mg/kg	40	1						342		

(a): UET value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(b): AET value, in NOAA, Screening Quick Reference Table for Organics in Marine Sediment
(c): LEL value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(d): Value of 1,500 µmhos/cm used based on literature

Table 57: Environmental Parameters from Previous Sampling

Parameter	Units	Drinking water (CDWQS)	Discharge standards - SDWPC		Screening levels for sediments - USEPA	Settling pond waste water (before change) – dissolved – Site 6, 2010	Settling pond waste water (after change) – dissolved – site 6, 2010	Settling pond waste water (after change) – total – site 6, 2010	Settling pond waste water (after change) – total – site 6, 2010	Settling pond sludge	Rice Husk char Sample (average of four samples for metals
			Protected public water area	Public water area and sewer	ARCS (EPA) for sediments						
Code											
Laboratory						SETN	SETN	SETN	SETN	SETN	SETN
Aluminium	mg/l or kg			0.087 (NOAA)		<0.01	0.166	8.18	8.99	3619	92 – 543
Antimony	mg/l				3.0					<3.0	
Arsenic	mg/l (mg/kg)	0.05	0.1	1	10.79	<0.05	<0.05	<0.25	<0.25	<1.5	
Barium	mg/l			0.0039 (NOAA)		0.143	0.079	0.88	0.89	711.4	< 1.79 - < 2.5
Beryllium	mg/l			0.00066 (NOAA)		<0.1	<0.1	<0.5	<0.5	<3.0	< 3.59 - < 5.00
BOD5	DO mg/l		30	80							
Boron	mg/l (mg/kg)		1	5		<0.02	<0.02	0.1	0.1	516	1.81 – 5.38
Cadmium	mg/l (mg/kg)	0.003	0.1	0.5	0.58	<0.01	<0.01	<0.05	<0.05	<0.3	< 0.36 - < 0.5
Calcium	mg/l					15.55	17.49	59.4	51.2	22.7%	609 – 1940

Chloride	mg/l	250	500	700							
Chromium	mg/l (mg/kg)	0.05	0.05	0.5	36.29	< 0.03	< 0.03	<0.25	<0.25	8.0	< 1.44 - < 2.5
Cobalt	mg/l (mg/kg)	0.003								<1.5	
COD	DO mg/l		50	100							
Copper	mg/l (mg/kg)	1	0.2	1	28.01			1.42	2.25		8.2 – 15.3
Dissolved oxygen	DO mg/l		> 2								
Electrical conductivity	ms/cm		-								
Fluoride	mg/l	1.5	-								
Grease & oil	mg/l		5								
Iron	mg/l	0.3	1	20	18.84%	0.51	0.05	2.47	1.14	1.05%	66 - 107
Lead	mg/l	0.01	0.1	1	37.00	<0.05	<0.05	<0.15	<0.15	43.9	< 2.32 – 28.2
Magnesium						4.46	2.167	3.48	3.09	2.45%	162 – 658
Manganese	mg/l	0.1	1	5	630.00	1.013	0.782	0.42	<0.05	2688	135 – 470
Mercury	mg/l (mg/kg)	0.001	0.002	0.05	0.18 (TEC)	<0.05	<0.05	<0.25	<0.25		< 1.79 - < 2.5
Molybdenum	mg/l (mg/kg)		0.1	1.0						<1.5	
Nickel	mg/l (mg/kg)	0.02	0.2	1.0	19.51	<0.04	<0.04	<0.2	<0.2	32.6	< 1.39 – 1.5
Nitrate	mg/l as NO_3^-	50	10	20							
Potassium	mg/l			373 (NOAA)		96.0	54.55	7.8	23.6	1.64%	595 – 2418
pH	pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0		8.401	7.087			11.47	7.8 – 10.0
Phosphate	mg/l as PO_4^{3-}	-	3	6							

Selenium	mg/l (mg/kg)	0.01	0.05	0.5						<3.0	
Silicon						23.72	14.78	2.08	1.77	4581	
Sodium	mg/l (mg/kg)	200	-	-		90.71	98.31	5.39	15.18	2428	76 – 650
Strontium	mg/l			1.5 (NOAA)		0.069	0.073	0.47	0.49	4594	1.87 – 9.10
Temperature	^{o}C										
Titanium	mg/l			2 (NOAA)		<0.01	<0.01	<0.05	<0.05	428.9	1.79 – 5.25
Total suspended solids / total solids	mg/l		50	80	98.00						
Total dissolved solids	mg/l	800	1000	2000							
Vanadium	mg/l			0.019 (NOAA)		0.08	0.083	<0.25	<0.25	7.1	< 1.75 - < 2.5
Zinc	mg/l (mg/kg)	3	1.0	3.0	98.00	<0.01	<0.01	<0.05	<0.05	482.3	11.7 – 44.2
BETX	mg/kg	125,300	249							500 - 1000	7.72 / 22.3
Total phenols	mg/kg									100 – 500	
PAHs		Dutch freshwater sediment intervention levels	Dutch freshwater sediment, target levels								
Acenaphthene	mg/kg	0.29[a]								73	

Acenaphthylene	mg/kg	0.16[a]								733	
Anthracene	mg/kg	1.60	0.039							< 0.01	
Benzo(a)anthracene	mg/kg	2.50	0.025							3.5	
Benzo(b)fluoranthene	mg/kg	1.80[b]								< 0.01	
Benzo(k)fluoranthene	mg/kg	38.00	0.38							1.1	
Benzo(a)pyrene	mg/kg	7.0	0.052							0.49	
Benzo(g,h,i)perylene	mg/kg	33.00	0.57							< 0.01	
Chrysene	mg/kg	35.00	8.10							< 0.01	
Dibenzo(a,h) anthracene	mg/kg	0.1[a]								4.9	
Fluoranthene	mg/kg	260	1								
Fluorene	mg/kg	0.30[a]								114	
Indeno(1,2,3-cd)pyrene	mg/kg	1.90	0.031							< 0.01	
1-Methylnaphthalene	mg/kg	0.094[d]								172	
2-Methylnaphthalene	mg/kg									152	
Naphthalene	mg/kg	17.00	0.12							1214	
Phenanthrene	mg/kg	3.1	3.3							586	
Pyrene	mg/kg	0.49[c]									
∑PAHs	mg/kg	40	1							3223	

(USEPA 16)											

(a): UET value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(b): AET value, in NOAA, Screening Quick Reference Table for Organics in Marine Sediment
(c): LEL value, in NOAA, Screening Quick Reference Table for Organics in Freshwater Sediment
(d): T50 toxicity assessment, Screening Quick Reference Table for Organics in Marine Sediment

Table 58: PAH Content of Rice Husk Char Samples

PAH (all in $mgkg^{-1}$)	RHC sample one	RHC sample two	RHC sample three	RHC sample four	RHC sample five (site 6)
Acenaphthene	0.81	1.00	2.08	0.48	0.26
Acenaphthylene	4.59	4.84	9.24	2.62	0.94
Anthracene	1.21	0.87	7.67	0.65	0.57
Benzo(a)anthracene	0.21	0.18	4.87	0.23	0.31
Benzo(b)fluoranthene	0.01	<0.05	2.95	<0.05	<0.05
Benzo(k)fluoranthene	0.06	<0.05	0.29	<0.05	<0.05
Benzo(a)pyrene	0.08	<0.05	3.20	<0.05	<0.05
Benzo(g,h,i)perylene	**< 0.04**	<0.05		<0.05	<0.05
Chrysene	0.39	0.31	7.38	0.25	0.74
Dibenzo(a,h)anthracene	<0.01	<0.05		<0.05	<0.05
Fluoranthene	3.73	1.54	15.52	1.27	1.77
Fluorene	0.38	0.52	1.23	0.45	0.41
Indeno(1,2,3-cd)pyrene	**< 0.01**	<0.05	<0.05	<0.05	<0.05
Naphthalene	**10.41**	10.95	5.13	4.11	3.09
Phenanthrene	7.63	5.42	30.91	3.74	5.13

Pyrene	2.19	1.21	13.78	1.09	1.42
∑PAHs (USEPA 16) (one sample)	**34.9**	26.8	**104.3**	14.9	**14.6**

7. Conclusions

This **Final Report** presents the work carried out by Nexus-Carbon for Development within the ''Emission Reduction Project Baseline, Feasibility and Environmental Study for EU SWITCH-Asia Waste to Energy (WtE) for the Rice Milling Sector in Cambodia'' framework.

The report highlights the next steps towards the identification of a clear carbon finance route for the Milling Sector in Cambodia as well as to a sustainable and environmental-friendly integration of rice-husk gasification technology in Cambodia.

Nexus analysed different carbon standard approaches for the development of a rice husk carbon project in the Kingdom of Cambodia. The analysis was carried out in the compliant as well as in the voluntary market with a focus on standalone projects.

Barrier Analysis to renewable energy production and consumption shows that there are no major legislative barriers in Cambodia. Legislative barriers may occur as a result of the environmental impact of disposal of by-products from the gasification process. A Law on Environmental Impact Assessment, setting out provisions, standards and procedures to carry out EIA in Cambodia, is currently being developed. Technical standards on water pollution control - Sub-Decree on Water Pollution Control and quality of drinking water - Drinking Water Quality Standards in particular need to be taken into account during the development of a carbon project in the rice-husk sector. Results from the Barrier Analysis highlight the presence of technical and socio-economic barriers.

The **Feasibility Assessment** shows a number of strengths and weaknesses for the WtE project. The project would be eligible as either a CDM or VGS standalone project using the CDM AMS I.B methodology ''*Mechanical energy for the user with or without electrical energy*". No GS methodology are available. In case a voluntary project is to be developed CDM methodologies need to be used.

Whilst the project is eligible at a technology level, the principal issues occur at the project level, specifically the lack of a defined project for carbon finance. This is most evident in establishing the additionality of the project. Whilst there is clearly a case for additionality for a project disseminating gasifiers, this would need to be additional to the commitments under the existing grant proposals. Carbon finance would be required to either assist the project scale up, to provide additional financial support for millers and to support development and implementation of sound environmental management plans for the RHG units.

Aside from the issues of project design the technology has potential to generate significant quantities of emissions reductions. Preliminary Emission Reductions calculations indicate an average of 28,872.66 tCO_2/yr under the CDM scenario and an average of 30,348.17 tCO_2/yr under the VGS scenario. At this stage, calculated ERs represent only an estimation due to the lack of coherent project design and dissemination plan. Once a clear project design is in place, ERs can be updated accordingly.

The **Financial Analysis** shows that project technology can generate emissions reductions at a level sufficient to cover the transaction costs of obtaining certification, although at present this is limited to the voluntary carbon market. The analysis shows that the ER breakeven prices to cover transaction costs are relatively low compared to the market price for VGS but it is slightly higher than the market price for CDM. The analysis also shows the minimum size for a Voluntary Gold Standard project to breakeven should consist of a yearly average minimum of 32 Rice-husk gasification units. In order to generate surplus revenue a VGS project would need to consist of more than 32 units. Owing to the current low price of credits, the CDM option requires a yearly average minimum of 154 Rice-husk gasification units to cover the cost of accessing carbon finance. In order to generate surplus revenue a CDM project would need to consist of more than 154 units.

However, the Feasibility Assessment conclusion should be treated with caution as the availability of grant funding to cover the initial dissemination raises additionality concerns. The decision to proceed with a carbon finance project would either require:

- A project redesign such that carbon finance is used to make gasifier more affordable
- Scale up beyond 150 gasifiers such that the existing grant period is a pilot phase and carbon finance is used to cover the scale up of the initiative.

The lack of specific project design and organization willing to act as the project proponent, may mean that it is more suitable as a Program of Activities (PoA).

A follow up study on the feasibility of PoA for the rice-husk gasification sector in Cambodia is currently being carried out by Nexus Carbon for Development. The objective is to develop a Conceptual Development Study and a Project Idea Note (PIN) to inform the development of a CDM PoA on rice husk gasification in Cambodia.

Nexus in cooperation with Dr Simon Shackley, Gasification Expert University of Edinburgh, carried out and **Environmental Impact Assessment** primarily looking at waste water, tar and rice-husk char. Results from the EIA indicates that the black waste water streams cause serious localized pollution of end disposal ponds and of streams into which the black water flows. Some of this pollution is persistent, as in accumulation of heavy metals in the water body, in particular manganese (and, to a lesser extent, copper, lead, iron, chromium and zinc), while zinc, chromium, magnesium, copper, nickel, lead and iron accumulate in some of the sediments tested. The high Electrical Conductivity measurements are indicative of the presence of negatively and positively charged ions and, where measured, moderate to high levels of nitrate, chloride and phosphate were discovered.

Of even more concern is the introduction of large amounts of organic molecules into the water bodies. The very high Biological and Chemical Oxygen Demand (where measured) indicates the high loading of ponds and streams with a complex mixture of organic compounds. This high loading and associated high BOD/COD is reflected by low measured DO levels and effectively kills-of other forms of life in ponds and streams such as fish, frogs, plants and macroinvetebrates (insects, spiders, crustaceans) which are unable to survive in such low oxygen water bodies.

Very high levels of single benzene-ring type molecules (benzene, ethylbenzene, ortho-, meta- and para- benzene and toluene) were discovered in all the waste water and sediment samples tested. Heavier molecular weight polycyclic aromatic hydrocarbon (PAHs) molecules (composed of two, three, four and five-benzene rings) were discovered at very high levels in most of the waste water and sediment samples.

Whether the organic and inorganic pollution can disperse from the disposal ponds and marshy areas laterally or vertically through the water table is not known and was not tested for in this study. A more detailed hydrological analysis and survey would be required to determine whether this is a problem or not but there seems at least a possibility that dispersion could happen for more mobile pollutants.

The tars collected at the base of the syngas filters also contain very high levels of BETX and PAHs and need to be disposed of safely as a special waste. On the other hand, the rice husk char (RHC) is a clean material and typically contains acceptable levels of heavy metals and PAHs. However, in one case tested, the RHC had a somewhat higher concentration of PAHs and chemical analysis and a quantitative risk assessment is advised before such material is incorporated into agricultural soils. In terms of metal and organic contaminants, many RHC samples could be used at 20 or so tonne per hectare application levels with out introducing any environmental or health and safety risks, provided that they have not been contaminated with settling pond sludge. There are agronomic and economic considerations which will determine suitable application levels of RHC on agricultural soils. Too much RHC in soil could end up removing soil N by sorption, reducing availability for plants, especially in low N systems. Practically, farmers are unlikely to have the resources and time to apply large quantities of RHC on to their fields, as it will add to field operations.

None of the sites visited had an **Environmental Management Plan** (EMP) in place. While an EMP is not required in Cambodian law at the present time, development of such would be a useful way for operators and owners to meet their obligations under the laws which do cover the operation of biomass gasifiers and to comply with carbon standards. This includes the likely requirement in the next few years for a more detailed Environmental Impact Assessment (EIA). The legal framework is largely already in place, but requires more detailed sub-decrees and guidance and, most importantly, enforcement by regulatory agencies.

The Baseline study and the Environmental Impact Assessment revealed a number of areas for **capacity building** to enable millers to participate in a carbon finance project these include:

1. Data management plan and capacity building for millers
2. Environmental management plan
3. Healthy and safety guidelines and training
4. Non-discriminatory recruitment policy.

In the likelihood that a carbon project is to be developed within the WtE Project for the Rice Milling Sector in Cambodia the following steps should be prioritized:

- **Go-No go Decision**: SNV/organization in charge to convene a Board meeting to decide whether to go ahead with the development of the carbon project;
- **Selection of Project Participant**: organization to be chosen as project proponent and clear project design to be put into place;
- **Identification of funding source**: project proponent to identify main funding stream to cover upfront project costs not conflicting with ODA;
- **Letter of Agreement**: project proponent to prepare letter and send it to Cambodian DNA and EB;
- **Environmental and health and safety management plan**: project proponent with support from carbon specialist and in cooperation with millers to develop an environmental and health and safety management plan in accordance with CDM/VGS rules;
- **Data recording management plan**: project proponent with support from carbon specialist and in cooperation with millers to develop a management plan in accordance with monitoring requirements of CDM AMS.I.B methodology.

The following **supporting documents** are attached:

- **Supporting Document I** - Gantt Charts for Validation and Verification of a standalone carbon projects

- **Supporting Document II** - Emission Reductions Calculations spreadsheet
- **Supporting Document III** – Project Idea Note (PIN)

Annex 1

AMS-I.B Methodology Spotlight

Typical Project: Installation of renewable energy technologies such as hydropower, wind power and other technologies that provide mechanical energy that otherwise would have been supplied with fossil-fuel-based energy. Mechanical energy is used on-site by individual household(s) or user(s). Typical applications are wind-powered pumps, water mills and wind mills. The project may also produce electricity in addition to mechanical energy.

Type of GHG emissions mitigation action Renewable energy: Displacement of more-GHG-intensive fossil-fuel-based generation of mechanical power.

Important conditions under which the methodology is applicable: Operating characteristics of the project system (e.g. head vs. discharge and efficiency of irrigation pump) should be similar to or better than the system being replaced or that would have been replaced.

Important parameters to be monitored: An annual check of all systems or a sample thereof to ensure that they are still operating; Annual hours of operation can be estimated from total output (e.g. tonnes of grain milled); If applicable: quantity of each type of energy sources consumed (e.g. biomass, fossil fuel); Net calorific value and moisture content of biomass.

Figure 32 and 33 show respectively Baseline Scenario where mechanical energy would be produced using fossil-fuel-based technologies as opposed to Project Scenario where mechanical energy is produced (with or without electricity) using renewable energy technologies.

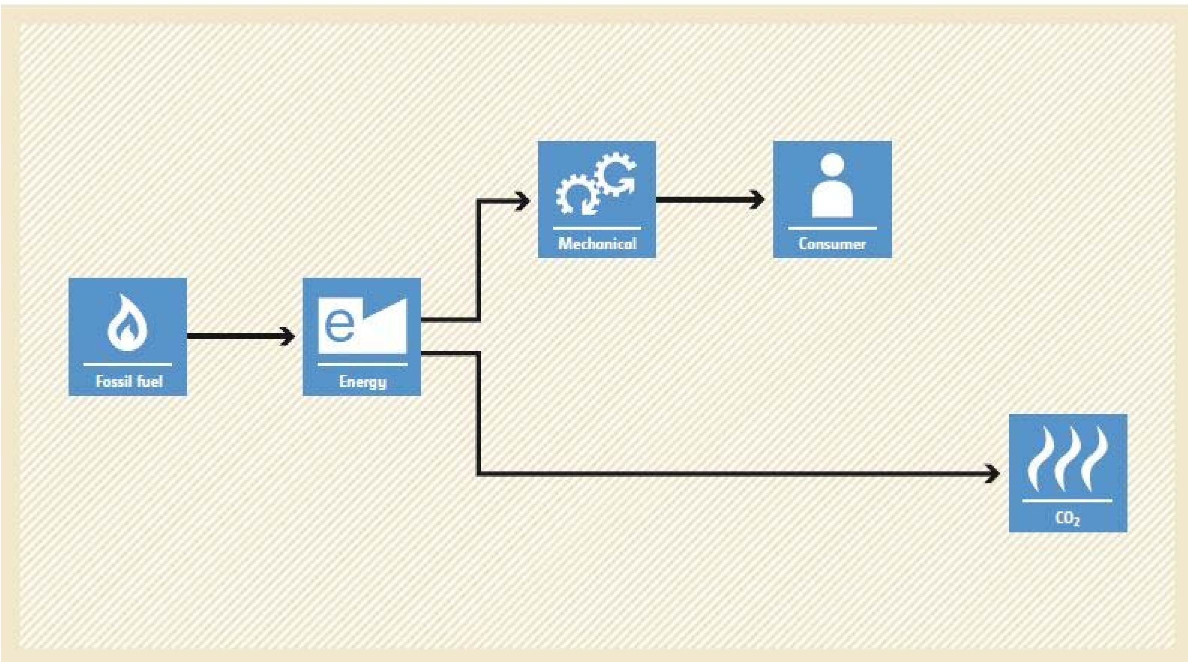

Figure 32: Baseline Scenario
Source: (CDM Methodology Booklet)

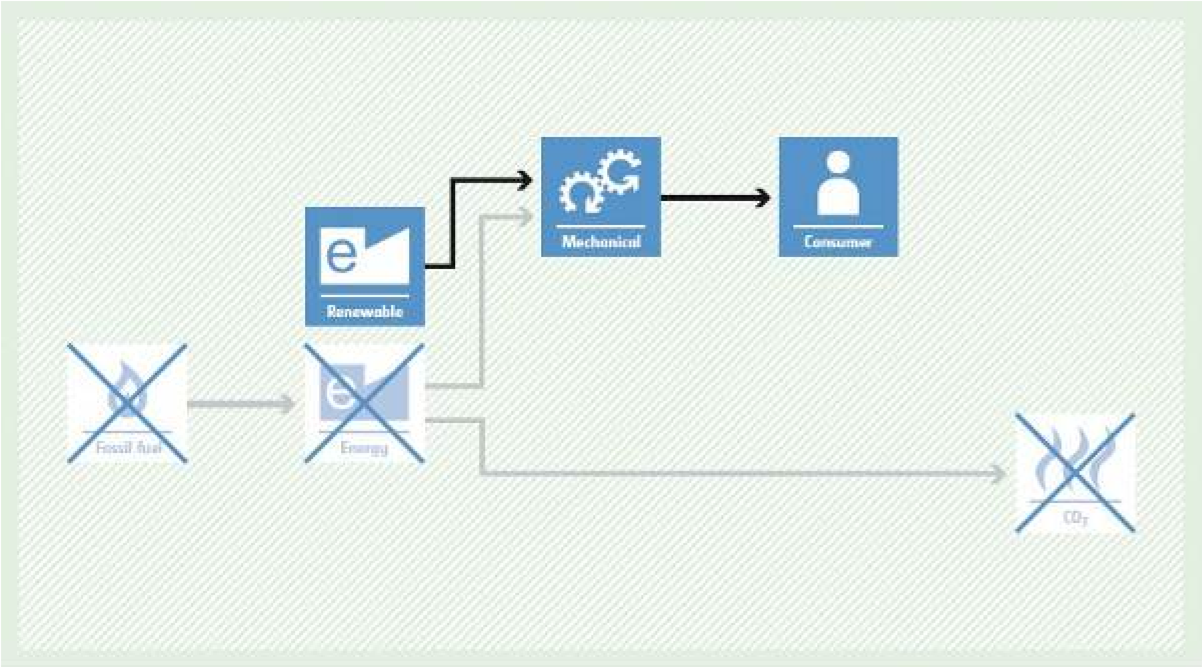

Figure 33: Project Scenario
Source: (CDM Methodology Booklet)

Annex 2

CDM Prior Consideration Form

Prior consideration of the CDM form (Version 02.0)	
This form is to be used by project participants in order to submit the notification of the commencement of the project activity and the intention to seek CDM status.[74]	
Is this Initial Submission? *(tick only if applicable)*	☐
Is this Notification of progress? *(tick only if applicable)*	☐
SECTION 1: PROJECT DETAILS	
A. Title of the CDM project activity	
B. Precise geographical location *(Geo-coordinates, Town/City, Country)*	
C. Brief description of the proposed project activity	

[74] The completed form should be sent to the Host Party DNA (find DNA contacts at: https://cdm.unfccc.int/DNA/index.html) and the UNFCCC secretariat (P.O. Box 260124 D-53153 Bonn Germany, OR cdmregistration@unfccc.int)

SECTION 2: NOTIFICATION OF PROGRESS MADE[75]
A. Brief description of progress made
B. Original title of the CDM project activity *(only if project title has changed since submission of initial Prior consideration form)*
SECTION 3: CONTACT INFORMATION

Name of the project participant: *(legal entity name)*	
Contact details of authorized representative:	Mr. ☐ Ms. ☐
Last name:	Telephone:
First name:	Fax:
Email:	Address:

[75] This section shall be filled in only for project activities not meeting the conditions specified in paragraph 7(a) or 7(b) of the CDM project cycle procedure, and shall be submitted in the frequency specified in paragraph 9 the same procedure.

Signature: ……………………………………… Date: ……………………………………

Annex 3

Official Development Aid Declaration

Letterhead of Project Owner
Date
Project reference
To: Gold Standard Foundation
Declaration of Non-Use of Official Development Assistance by Project Owner

[*Project Owner*]

As Project Owner of the above-referenced project, acting on behalf of all project participants, I now make the following representations:

[Authorised Representative:]

I hereby declare that I am duly and fully authorised by the project owner of the above referenced project, acting on behalf of all project participants, to make the following representations on Project Proponent's behalf:

I. Gold Standard Documentation.
I am familiar with the provisions of Gold Standard Documentation relevant to Official Development Assistance (ODA). I understand that the above-referenced project is not eligible for Gold Standard registration if the project receives or benefits from Official Development Assistance under the condition that some or all credits coming out of the project are transferred to the ODA donor country. I now expressly declare that no financing provided in connection with the above-referenced project has come from or will come from ODA that has been or will be provided under the condition, whether express or implied, that any or all of the credits [CERs, ERUs or VERs] issued as a result of the project's operation will be transferred directly or indirectly to the country of origin of the ODA.

II. Duty to Notify Upon Discovery.
If I learn or if I am given any reason to believe at any stage of project design or implementation that ODA has been used to support the development or implementation of the project, or that an entity providing ODA to the host country may at some point in the future benefit directly or indirectly from the credits generated from the project as a condition of investment, I will make this known to the Gold Standard immediately.

III. Sanctions.
I am fully aware that under Section 10 of the Gold Standard Terms and Conditions sanctions and damages may be incurred for the provision of false information related to Projects and/or Gold Standard credits.

Signed:
Name:
Title:
On behalf of:

Annex 4

Baseline Study Interviewee

Table 59: Baseline study interviewee

Final Field Work Plan							
No	**Name of rice miller**	**Telephone number**	**Village**	**Commune**	**District**	**Province**	**Interview date**
1	ChhunNgoun Hong	012 89 31 24	Mchheay	Samprouch	Staung	Kampong Thom	05/12/2012
2	AngSeak Kong	012 73 19 67	Kampong Kdey	Kampong Chin Tbong	Staung	Kampong Thom	05/12/2012
3	Sen Rith	012 91 72 94	Wat Svay	Sala Kamroek	Siem Reap	Siem Reap	08/12/2012
4	Srun Tong Hav	012 791 915	DounSva	Chaek Touk	Angkor Chum	Siem Reap	06/12/2012
5	Choeng Bunham[76]	012 76 93 71	Pechour	KraLagnn	Kralagnn	Siem Reap	06/12/2012
6	Chheng Kim Chhour	012 428 639	Wat Thmey	Phnom touch	Mongkul Borei	Banteay Mean Chey	07/12/2012
7	Om Set Thon	012 654 852	Pong Ro	Kampong Svay	SereiSophorn	Banteay Mean Chey	07/12/2012
8	Eat leangKheang	012 822 474	AndoungTreang	Sroma	Chhoeung Prey	Kampong Cham	11/12/2012
9	Leang Seng	017 755 855	AndoungTreang	Sroma	Chhoeung Prey	Kampong Cham	11/12/2012
10	Khun Gnoun	012 855 399	Anchargn	O Char	Battambang	Battambang	06/12/2012
11	Sroy Kim Se	092 84 31 47	Chhrey	Chhrey	Thmar Kol	Battambang	06/12/2012
12	Loy Thich	012 93 14 79	SalaBalat	Omal	Battambang	Battambang	09/12/2012
13	Hut ChhaiGnon	012 606 195	ThmorKol	Ta Pong	Thmar Kol	Battambang	08/12/2012
14	Thouk Ka	092 408 409	KoukTrob	Ta Moeurn	Thmar Kol	Battambang	08/12/2012
15	Soeng Chhang	012 65 11 94	ChhkaeKoun	Kouk Kmom	Thmar Kol	Battambang	07/12/2012
16	Vann Hom	012 781 078	ChhroNeang	Kouk Kmom	Thmar Kol	Battambang	08/12/2012
17	Heng Sokha	012 66 26 16	O pangman	Ta kream	Banan	Battambang	05/12/2012
18	Keav Vutha	012 25 38 56	Knar Ampil	Veal Pung	Oudong	Kampong Speu	08/12/2012
19	Sok Khom	012 66 63 80	Sangva	Kampong Loung	Ponhea Lour	Kandal	05/12/2012

[76] Millers highlighted in green have a RHG installed.

Final Field Work Plan							
No	Name of rice miller	Telephone number	Village	Commune	District	Province	Interview date
20	Srey Chanthoeurn	012 46 46 99	Ta Por	Samrong tong	Trapang Kong	Kampong Speu	08/12/2012
21	Ly Long	012 60 96 67	Bat Doeung	Khseim Khsan	Udong	Kampong Speu	06/12/2012
22	Taing LeangSeng	012 95 63 76	Lvea	Lvea	Preas Sdech	Prey Veng	06/12/2012
23	Tam Kokveng	012 96 23 52	PorChentam	Svay Antor	SvayAntor	Prey Veng	05/12/2012
24	Kim Srun	092 77 70 84	Thmey	Kong Chey	Orang Ov	Kampong Cham	06/12/2012
25	Taing Sithoung	012 86 24 14, 088 84 25 111	ToulSralaov	Kung Chey	Orang Ov	Kampong Cham	07/12/2012
26	Bei Kim Seang	011 66 26 25	ToulSralaov	Kong Chey	Orang Ov	Kampong Cham	07/12/2012
27	Vinh Cheang	012 93 37 37	Veang Kandeang	Chub	Tbong Khmom	Kampong Cham	07/12/2012
28	Keat Sothea	012 33 44 57	Chhourng Wat	Kong Chey	Orang Ov	Kampong Cham	08/12/2012
29	Pheav Heng	012 94 12 24, 097 22 11 112	Pha Av	Pha Av	Ba Theay	Kampong Cham	05/12/2012
30	Se Laluch	097 63 68 686	Taing Kouk	Lvea	Prey Chhor	Kampong Cham	05/12/2012
31	Sek Savoeurn	92815771	Ampil Thom	Khvet Thom	Prey Chhor	Kampong Cham	05/12/2012
32	Heng SiengHeurn	012 60 53 00	Sleng	Chrai Vien	Prey Chhor	Kampong Cham	06/12/2012
33	Ngeab Chhiv	012 76 19 09, 011 65 70 35	Sleng	Chhrey Vien	Prey Chhor	Kampong Cham	06/12/2012
34	Mao Srun	012 50 24 02, 012 39 71 39	Trapeang Krasaing	Trapeang Preah	Prey Chhor	Kampong Cham	07/12/2012
35	KhiToem Try	012 56 23 60	Sleng	ChhreyVien	Prey Chhor	Kampong Cham	07/12/2012

Annex 5

Registration Completeness and Compliance Checklist

See attached excel file.

Annex 6

EIA: Key Parameters

Table 60: Key Parameters for Testing in Waste Water, Sludges, Soils and Rice Husk Char

Parameter	Formula	Units	Drinking water (CDWQS)	Discharge standards - SDWPC		Biochar standards (IBI)	Detection limit	Method	Laboratory
				Protected public water area	Public water area and sewer				TBC
Arsenic	As	mg/l (mg/kg)	0.05	0.1	1	10	1.5 ppb	AFS	RDIC – PP NWSS
Benzene		ug/l	10						NWSS
BOD	-	DO mg/l		30	80			BOD5	RDIC – PP
Boron	Bo	mg/l (mg/kg)		1	5	20			NWSS
Cadmium	Cd	mg/l (mg/kg)	0.003	0.1	0.5	1.2			NWSS
Chloride	Cl-	mg/l	250	500	700		0.18	IC	RDIC – PP NWSS
Chlorine	Cl	mg/kg		1.0	2.0	90			NWSS
Chromium	Cr	mg/l (mg/kg)	0.05	0.05	0.5	60			NWSS
Cobalt	Co	mg/l (mg/kg)				14			NWSS
COD		DO mg/l		50	100				RDIC – PP
Copper	Cu	mg/l (mg/kg)	1	0.2	1	143		Electrode	NWSS
Dissolved oxygen		DO mg/l		> 2	> 1			UEDIN instrument	In situ
Electrical conductivity				-	-			UEDIN instrument	In situ
Fluoride	F	mg/l	1.5	-	-		0.35	IC	RDIC – PP
Grease & oil		mg/l		5	15				RDIC – PP
Iron	Fe	mg/l	0.3	1	20			CS	RDIC – PP NWSS
Lead	Pb	mg/l	0.01	0.1	1	125		Electrode	RDIC – PP NWSS
Manganese	Mm	mg/l	0.1	1	5		0.03	CS	RDIC – PP

									NWSS
Mercury	Hg	mg/l (mg/kg)	0.001	0.002	0.05	0.5		AFS	RDIC – PP NWSS
Molybdenum	Mo	mg/l (mg/kg)		0.1	1.0	5			NWSS
Nickel	Ni	mg/l (mg/kg)	0.02	0.2	1.0	25			NWSS
Nitrate	NO_3^-	mg/l as NO_3^-	50	10	20		0.13	IC	RDIC – PP
∑PAHs (EPA 16)		mg/l (mg/kg)				6		Own method	NWSS
pH		pH units	6.5 – 8.5	6.0 – 9.0	5.0 – 9.0			pH meter	RDIC – PP
Phenols (total)		mg/l (mg/kg)		0.1	1.2			Own method	NWSS
Phosphate	PO_4^{3}	mg/l as PO_4^{3-}	-	3	6		0.62	IC	RDIC – PP
Selenium	Se	mg/l (mg/kg)	0.01	0.05	0.5	10			NWSS
Sodium	Na	mg/l (mg/kg)	200	-	-	140		IC	RDIC – PP NWSS
Sulphate	SO_4^{2-}	mg/l	250	300	500		0.11	IC	
Total suspended solids		mg/l		50	80				RDIC – PP
Total dissolved solids		mg/l	800	1000	2000				RDIC – PP
Zinc	Zn	mg/l (mg/kg)	3	1.0	3.0	320			NWSS

CDWQS = Cambodian Drinking Water Quality Standards (Draft Proposed Cambodian National Drinking Water Quality Standards, Version 4, as of June 21, 2003).
SDWPC = Sub-Decree on Water Pollution Control, No. 27, ANRK.BK Phnom Penh, April 6th, 1999, Annex 2.
IBI = International Biochar Initiative, Standardized Product Definition and Product Testing Guidelines for Biochar That is Used in Soil, 5th April, 2012
Methods: AFS: Atomic Fluorescence Spectrophotometer; IC: ion chromatography; CS: Colorimetric spectrophotometry
Laboratories: RDIC – PP: Resource Development International Cambodia – Resource Laboratory, Phnom Penh; NWSS: Northumbrian Water Scientific Services (Accredited laboratory)

Table 61: Identity of Key Toxic and / or Persistent Organic Pollutants

Toxic and / or Persistent Organic Pollutant (POPs)
1. Polycyclic aromatic hydrocarbons (PAHs)
Acenaphthene
Acenaphthylene
Anthracene
Benz(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Chrysene
Dibenz(a,h)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Napthalene
Phenathrene
Pyrene
PAH Total (EPA 16) = ∑ above
2. BETX
Benzene
Ethylbenzene
Toluene
Xylene
3. Phenols

Annex 7

EIA Photographs

Figure 34: Measuring water quality in disposal pond (site 1) with Hach multi-probe

Figure 35: Measuring water quality in settling ponds (site 1) with Hach multi-probe

Figure 36: Waste water settling pond (site 4)

Figure 37: Waste water clean-up system (Ankur Scientific Pvt Ltd.) (site 4)

Figure 38: Clean water effluent from the waste water treatment system (site 4)

Figure 39: Disposal pond for waste water (site 4)

Figure 40: Waste water outlet from settling pond to disposal pond (site 4)

Figure 41: Clean pond (no waste water input) close to the gasification unit (site 4)

Figure 42: Pile of rice husk char (site 5)

Figure 43: Waste water discharge from settling pond (black water pipe) (site 7)

Figure 44: Waste water stream from settling pond (site 7)

Figure 45: Waste water sampling in marshy area behind gasifier (site 8)

Figure 46: 'Clean' pond adjacent to disposal pond (site 9) (showing signs of eutrophication)

Figure 47: Waste water stream (site 9)

Figure 48: Rice husk char piles, with grazing animals (site 9)

Annex 8

EMP Precedents in carbon projects

Table 62: Environmental Management Plans precedents in CDM projects

Project Number	Title	Environmental Impacts/Mitigation Measure as per Project Development Document
CDM Project 0363	Angkor Bio Cogen Rice Husk Power Project[77]	**No Environmental Impact Assessment (EIA) has been carried out** as ''EIA is not required for a power generation project of less than 5MW in capacity except for hydropower project for which EIA is required if the generation capacity is greater than 1MW in Cambodia.'' **No major Environmental Impacts have been identified**: ''the Project does not cause negative environmental impacts. The environmental concerns relating to steam turbine is virtually zero. Other points noted for ABC's plant are following: 1. the combustion of rice husk may present some concerns because of the low density of the husk and the high particulate in the flue gas. However, automation of the combustion control as well as wet scrubber will help in reducing the particular emissions at the stack. SO2 emissions from combusting biomass will be minimal and be reduced compared to using fossil fuel. NOx emissions will also be low and maintained within the prevailing emission standards promulgated by the Sub-Decree on Air Pollution Control and Noise Disturbance (2000) under the jurisdiction of Ministry of Environment (MOE). The monitoring of the emissions will be decided in consultation with the MOE. **Mitigation Measures**: ''wastewater will be treated at site before being released to either natural ponds or small waterways. Regular testing of effluent will be carried out by in -house operations team in order to ensure that the effluent standards are in line with the Sub-Decree on Water Pollution Control which is also administered by MOE.''
CDM Project 1187	Bundle of 100 village biomass gasifier based power plants totalling 5.15 MW for decentralized Energy Systems India Pvt. in Bihar[78];	**No environmental impacts/mitigation measures** have been identified in the PDD;

[77] http://cdm.unfccc.int/Projects/DB/DNV-CUK1144657688.42/view

[78] http://cdm.unfccc.int/Projects/DB/DNV-CUK1182246264.01/view

CDM Project 1302	Biomass gasification based Power Generation by Arashi Hi-Tech Bio-Power Private Limited[79];	'' There is no GHG emission from this project activity. Combustion of biomass in the proposed project does not result in net increase in GHG emissions of CO2, CH4 and NOx. There is no fly ash or solid waste from this biomass gasification process. There is no significant an environmental impact due to these project activity hence environmental impacts assessment is not required for this project activity.''
CDM Project 1760	GCL biomass gasification based power generation[80]	**No Environmental Impact Assessment (EIA) has been carried out** as ''the project activity is not required to conduct Environment impact Assessment by the host country. The proposed project would utilize the biomass for power generation and combust in a controlled way, this thereby eliminates the environmental consequences of fugitive emissions that arise due to the usual methods of biomass disposal i.e., open air burning or dumping. The SOx, and NOx, emissions from biomass combustion will be much lower compared to the conventional fossil fuel, coal, and is well within the limits as prescribed by the different state and national environmental statutes.'' **Mitigation Measures** **Ash disposal system:** Woody biomass contains ash to the extent of 1%. This ash, the by-product of Gasifier system, is also having certain quantity of unused carbon. However this ash cannot be used for reprocessing in Gasifier. Ash will be removed from the bottom of the Gasifier through proprietary reduction bed control system continuously and in wet mode. Ash lumps from drying pits will be filled in bags and sold to brick manufacturers in nearby area or disposed off to nearby filling sites. This ash is non-toxic can also be used as fertilizer also. Tractor trolleys and trucks will be used of carrying the ash to the ash fill area.

[79] http://cdm.unfccc.int/filestorage/X/W/8/XW8DG7ELSZVRQ0IY18XM4IUNK3TJHB/PDD.pdf?t=NHZ8bWl1enlpfDDflnUpGpKT34Ywt50aZOi-
[80] https://cdm.unfccc.int/filestorage/J/C/I/JCIL4W237AQ5TP6GKN9EYF0SV8OU1D/GCL%20PDD%20clean.pdf?t=Q1R8bWl2MDRufDAZTxEkfjnx3qH1j6m5uoDy

		Disposal of char: Char from Gasifier has a reasonably high calorific value (of around 3000 Kcal/kg.) and can be useful as a fuel for small-scale industries requiring thermal energy. It can also be used as filler-cum-fuel by brick kilns filler in concrete hollow bricks, as a raw material in manufacture of precipitate silica etc. and hence is planned to be sold off to such units at a nominal price. The quantity of char produced is very small, approx. 3 % of weight of the biomass used.
CDM Project 2447	Biomass Gasification based electricity generation by M/s Obeetee Private limited (OPL) at Sant Ravidas Nagar district, Uttar Pradesh[81]	**No Environmental Impact Assessment (EIA) has been carried out**: ''according to Indian regulations Biomass gasification based power plants are not included in this list and thus an EIA is not required. The project activity has no significant impact on the environment.'' **Mitigation Measures**: the waste water generated by the gasifier will be treated in the ETP, after proper treatment the water will be used for cultivation.
CDM Project 2913	Biomass gasification based power generation by Beach Minerals Company Private Limited in India[82]	**No Environmental Impact Assessment (EIA) has been carried out**: ''according to Indian regulation, the implementation of small scale biomass plants does not require an Environmental Impact Assessment (EIA). This project activity is a small scale project activity. **Environmental Impacts**: ''there is no significant an environmental impact due to this project activity hence environmental impacts assessment is not required for this project activity.''

[81] https://cdm.unfccc.int/filestorage/4/2/B/42B3NDQT0SMYUWXFI5CVZJRGO96A1H/OPL%20PDD%20clean.pdf?t=OE98bWl2MGx4fDCoaU-13d2DeXnvQto3fELp
[82] http://cdm.unfccc.int/filestorage/9/P/0/9P0R5IHSAX6M1NJLDW2CBQYT3FK7UV/Revised%20PDD%20Version%207%20-%20Clean.pdf?t=Q0x8bWl2MHZlfDBN8-Iu2w_VIJNm6ZtnzBos

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